



WAAREE ENERGIES

Internship Learning Log

Solar Module Manufacturing — from cell to shipped panel

Prepared by Varish

• 4-Day Summary • Chikli, Vapi • June 2026

Internship Overview



DATES

June 15–19, 2026



LOCATION

Chikli, Vapi
Gujarat



PRIMARY MENTORS

Dr. Prasann Shah &
Arjun Patel

In the summer of 2026, during my school break after IBDP Year 1 (Grade 11), I interned with the largest non-Chinese solar module manufacturer in the world.

MY LEARNING OBJECTIVES



Bridge the gap between theory and the reality of engineering at manufacturing scale



Understand how electrical testing works — I-V curves, efficiency measurement, quality gates



See how industrial automation and control systems operate on the factory floor — connecting to my robotics background



Observe how engineers communicate and problem-solve in a live industrial environment

Company Overview

22.77 GW

Total module capacity (India + US)

5.4 GW

Solar cell capacity (India's largest)

₹26,537 Cr

FY26 revenue (3-yr CAGR 58%)

25+

Countries with active sales

WHAT THEY MAKE

- Solar PV Modules — PERC, TOPCon, HJT, Bifacial (G12/G12R)
- Solar Cells — 5.4 GW at Chikli; India's largest cell facility
- Inverters & BESS — Li-ion storage (scaling to 20 GWh)
- Electrolysers — Green hydrogen (1 GW plant, Valsad)
- Solar Glass — 2,500 TPD plant under construction

INTEGRATED BUSINESS MODEL

Waaree 1.026 GW modules
5.4 GW cells**Waaree 2.0**28 GW modules
15 GW cells**~\$3.5Bn capex — Waaree 1.0 → 2.0****Value Chain**

\$1.3Bn capex — ingots, wafers, glass

**Power Tech**

4 GW inverters + 20 GWh BESS

**EPC & O&M**

TAM: ~\$1Tn today → ~\$4Tn by 2035

WHY WAAREE MATTERS

- #1 non-Chinese solar module manufacturer globally
- First Indian company to hit 1 GW+ output in a single month (Nov 2025)
- US facility (2.6 GW) — positioned to benefit from anti-China tariffs
- ₹30,000 Cr+ capex across modules, cells, BESS, hydrogen, glass & T&D
- ALMM-approved — qualifies for all Govt of India solar procurement

WAAREE FUTURE PLANS

- Green Hydrogen – Electrolyser Plant
- BESS Plant (Battery Packs + Cells)
- Backward / Vertical Integration

The Vapi–Chikli Facility

FACILITY SNAPSHOT

Location	Chikli, Vapi — Gujarat
Primary Role	Solar cell manufacturing (Stage 3)
Cell Capacity	5.4 GW — India's largest single-site cell plant
Technology	G12R TOPCon cells — 25.54% module efficiency
Certifications	IEC 61215 / IEC 61730 — ALMM List-II ready

WHERE VAPI SITS IN THE VALUE CHAIN

Polysilicon	China-dominant; India near-absent
Ingots & Wafers	Waaree planning 10 GW by 2028
Cell Fabrication	Chikli — 5.4 GW TOPCon ★
Module Assembly	Vapi — internship site (Stage 4) ★
Inverters / BESS	Waaree expanding to 4 GW / 20 GWh
EPC & Grid	5 GWp commissioned; ₹3,331 Cr revenue

MY PERSPECTIVE — WHY WAAREE FOR THIS INTERNSHIP

1

Most credible name in Indian solar manufacturing — to understand how clean energy is built at scale, this is the right place.

2

Vapi offers real manufacturing and electrical engineering exposure — exactly what I need to connect IBDP Physics to real-world application.

3

India's renewable energy transition is one of the defining engineering challenges of our generation, and Waaree is at its centre.

Orientation, Factory Tour & Internship Plan

ENTRY & ORIENTATION

Security & check-in: Cleared tight security before entering the Waaree campus.

Planning session: Visited the OHF building to map out a 5-day schedule and learn about Waaree operations and future goals.

Safety briefing: Thorough induction covering all plant protocols before any floor access.

Technical induction: Lecture covering raw materials, module manufacturing procedure and finished panel specifications.

Campus discipline: Observed all vehicles strictly following the 20 kmph speed limit on site.

FACTORY TOUR

Mandatory PPE: Safety boots and hairnets required for all — workers wore either a hairnet or cap on the floor.

Logistics awareness: Forklifts emerge suddenly from between stacked box rows — constant vigilance required.

Glass sorting: First station: incoming glass sheets are inspected and sorted before entering the line.

Cell making & stringing: Multiple machines soldering and quality-testing half-cells into strings.

Back-end assembly: EVA lamination, vacuum processing, trimming, aluminium framing with sealant, and final flash testing.

INTERNSHIP PLAN — 4-DAY SCHEDULE

Day 1

Module Basics & Back-End

Layer structure, cell interconnection, lamination & framing

Day 2

Testing & Build Flow

Reliability tests and the full cell-to-panel production line

Day 3

Incoming Material QC

Sampling & testing every raw material before it enters the line

Day 4

Utilities & Raw Materials

Plant power, support equipment and materials behind every panel

Key Observations

1



Scale that redefines expectations

Witnessing 1 GW+ monthly output in practice — not as a statistic — fundamentally changed my sense of what industrial scale means.

2



Two breeds of engineer

A clear distinction emerged between engineers who design and build machines and those who operate them at production scale. During my last year's internship, I saw machine design; here I saw mass deployment — both are essential, and both fascinated me.

3



Automation balanced with human judgement

The shopfloor blends automation and skilled intervention with precision. Defective cells in a string are swapped manually — more efficient than discarding an entire string. The logic of when to automate and when to intervene is itself an engineering discipline.

4



Precision at nano scale, deployed at giga scale

High-precision machines — EL imagers, Autobus, UTM's — operated by trained engineers to maintain sub-millimetre tolerances across thousands of panels daily.

5



The human architecture of continuous production

24/7 output is not just machines — it is structured shifts, mandatory and voluntary breaks, and deliberate fatigue management. Operational continuity is as much a people challenge as an engineering one.



SECTION

Day wise Internship Log

A day-by-day account of what was observed, learned and explored across four days on the factory floor.



What I Learned, Day by Day

A four-day walk through how Waaree designs, builds and quality-checks a solar module.



DAY 1

Module Basics & Back-End

Layer structure, cell interconnection and the lamination-framing process.



DAY 2

Testing & Build Flow

Reliability/certification tests and the full cell-to-panel production line.



DAY 3

Incoming Material QC

How every raw material is sampled and tested before it enters the line.



DAY 4

Utilities & Raw Materials

Plant power, support equipment and the materials that make a panel.



DAY 1

Module Basics & Back-End Process

How a solar module is layered, interconnected and assembled.



The Solar Module — a Five-Layer Sandwich

1 Front glass

2 Front EVA

3 Solar cell

4 Back EVA

5 Back glass



Glass

Semi-toughened, scratch-resistant, with an anti-reflective coating (ARC). The inner face is textured so EVA bonds well; sheets are handled by vacuum pickers.



EVA encapsulant

Shields the cell from the glass and from vibration. It turns transparent when melted, lets sunlight through, and adds UV protection with low degradation.



Cell

Made from silicon and cut into half-cells to reduce losses; this is the layer that actually generates electricity.

Connecting the Cells — Tabber & Stringer

An automatic tabber-and-stringer machine solders cells together into strings before they are laid up into a panel.

16 BB

Busbars per cell (BB = bus bar) carry the current across the cell.

12 cells

One string is made of 12 cells joined in series.



Silver fingers & dots

The thin white lines and dots on a cell are screen-printed silver — the dots mark where soldering happens.



Ribbon interconnect

A copper ribbon is soldered cell-to-cell, alternating top and bottom so current flows through the whole string.



Solder-strength check

A universal testing machine pulls each joint: too loose = weak solder; too tight = brittle, the cell can crack.

The Back-End: Lamination to Framing

1

Lamination

EVA is melted to bond the glass, cells and back sheet into one sealed laminate.

2

Vacuum

All trapped air is drawn out to prevent corrosion and bubbles inside the panel.

3

Cooling

The panel is held near 50 °C so the EVA cools and sets evenly.



Framing & sealing. An aluminium frame is added with RTV (room-temperature-vulcanising) sealant to keep water out. Sealant is weighed before and after so the exact amount per frame and junction box is recorded.



Power test. A flash/pump test measures how much energy the finished panel actually produces before it moves on.



DAY 2

Reliability Testing & Manufacturing Flow

Why modules are tested — and how they travel from cell to shipped panel.



Why & How Modules Are Tested



Two main standards

Testing follows two principal international standards; every new material is qualified before use.



Two goals

Tests check both efficiency (power output) and lifespan (how the module ages over 25+ years).



Shared baseline

The first five module tests every panel undergoes are the same, then product-specific tests follow.



First-line check

Visual inspection

The panel sits on a lightbox; lamps switch on from the front and back so any internal defect becomes visible to the inspector.

Tests fall into four families — shown next.

Reliability Test Catalog



Electrical & Performance

EL imaging (an X-ray-like photo of the cells) • Sun-simulator efficiency • Insulation & wet-leakage • Continuity • Bypass diode • Impulse voltage • Reverse-current overload



Environmental & Climate

Damp heat • Humidity freeze • Thermal cycling (+85 ↔ -45 °C) • UV preconditioning • Salt-mist corrosion • LeTID • PID (96 h, high V + humidity)



Mechanical & Structural

Static mechanical load (push/pull) • Bending (flexible panels) • Robustness of terminations (junction box pull) • Module breakage • Peel & lap-shear bonding



Safety & Handling

Cut susceptibility • Sharp-edge • Accessibility (blade probe) • Hail impact • Water-leak immersion • Visual inspection

Production Line — Cell to Shipped Panel

1

Cells in

Silicon cells arrive in rows and are cut into half-cells for lower losses.

2

Stringing

Ribbons run through flux and solder to cells in an alternating top/bottom pattern; an aluminium plate holds them as a conveyor melts the joints.

3

EL check

An electroluminescence photo confirms every solder joint is sound before the cells go further.

4

Layup

Six rows sit on each half of the glass + EVA board; three aligned holes register the layers and tape keeps cell spacing consistent.

5

Lamination

Printed glass is laminated, then placed and aligned with vacuum pickers.

6

Inspection

A computer scans for defects; any faulty cell is swapped out in the repair area, then components are taped together.

7

Cure & test

≈5 h to cool the silicon, a sun-simulator efficiency check, and automated visual inspection with barcode + WAAREE logo.

8

Pack & ship

Defective panels are pulled and returned; good panels are packed and finally shipped.



DAY 3

Incoming Material Quality Checks

Every raw material is sampled and tested before it reaches the line.



Sampling the Cells, Metals & Encapsulant

Almost every incoming material is sample-tested on Waaree's own equipment and matched against the ordered specification.

Material	What's checked	Tool / method
Solar cell	Dimensions, electrical ratings, efficiency and white-spot defects	Vernier; sun simulator
Ribbon & busbar	Diameter, length, tensile strength and elasticity	Vernier; UTM stretch-to-break test
Aluminium frame	Dimensions, hardness and anodised coating	Vernier + tape; hardness tester; rust-analysis machine
EVA	Thermal stability, tensile strength and lamination shrinkage	Xenon chamber 30 h @ ~70 °C, 6 h cool, then weigh; peel test

Glass, Junction Box & Consumables

Material	What's checked	Tool / method
Glass	Dimensions, transparency and impact strength	Steel-ball drop test
Junction box	Water-proofing of the sealed joint	Seal applied, then 30 min water immersion
Sealant	Hardness and adhesion	Spread on a sheet and checked
Flux	Acidity	Titration against hydrochloric acid
Cardboard box	Compression / crush strength	Force-to-collapse on a BS testing machine



DAY 4

Plant Utilities & Raw Materials

The power, support equipment and materials behind every panel.



Electrical Infrastructure



Incoming supply

11,000 V

Three-phase power arrives at 11 kV and is stepped down in the plant's control room before it reaches the line.

Circuit breakers protect the plant

MCB

Miniature circuit breaker — low-current branch protection.

ACB

Air circuit breaker — larger loads; uses compressed air to clear the arc.

VCB

Vacuum circuit breaker — high-voltage switching in a sealed vacuum.

Support & Utility Equipment



Compressors

CFM

Supply compressed air; capacity rated in CFM.



Chiller

TR

Provides process cooling; capacity rated in TR.



Dryer

Removes humidity from the compressed air.



AHU

Air-handling unit — filters and conditions air.



Cooling tower

Rejects waste heat from the cooling loop.



Transformer

kVA

Steps voltage down; capacity rated in kVA.

Raw Materials & Their Roles



EVA / EPE / POE

The encapsulant (ethylene-vinyl acetate; POE = polyolefin elastomer). Passes light, resists UV and degrades slowly.



Ribbon

Copper coated with a tin-lead mix (~60/40) to solder one cell to the next.



Tape

Keeps an even gap between cells and stops air bubbles forming.



Glass-to-glass

Semi-toughened glass on both faces makes the module bifacial — it generates from both sides.

Bill of materials

- Glass
- EVA / EPE / POE
- Solar cell
- Ribbon
- Flux
- Busbar
- Tape
- Aluminium frame
- RTV sealant
- Junction box
- IPA (cleaner)
- Barcode & RFID
- WAAREE logo
- Corner protector
- Back label

Key Takeaways



A module is a sealed sandwich

Glass, EVA and silicon cells, laminated and framed to last for decades.



One continuous flow

Cells are strung, laid up, laminated, tested and packed on a single automated line.



Quality at every stage

Checks run from incoming material, to in-line EL imaging, to a full reliability test suite.



Built to standards

Testing targets both efficiency and a 25-year-plus working life under international standards.