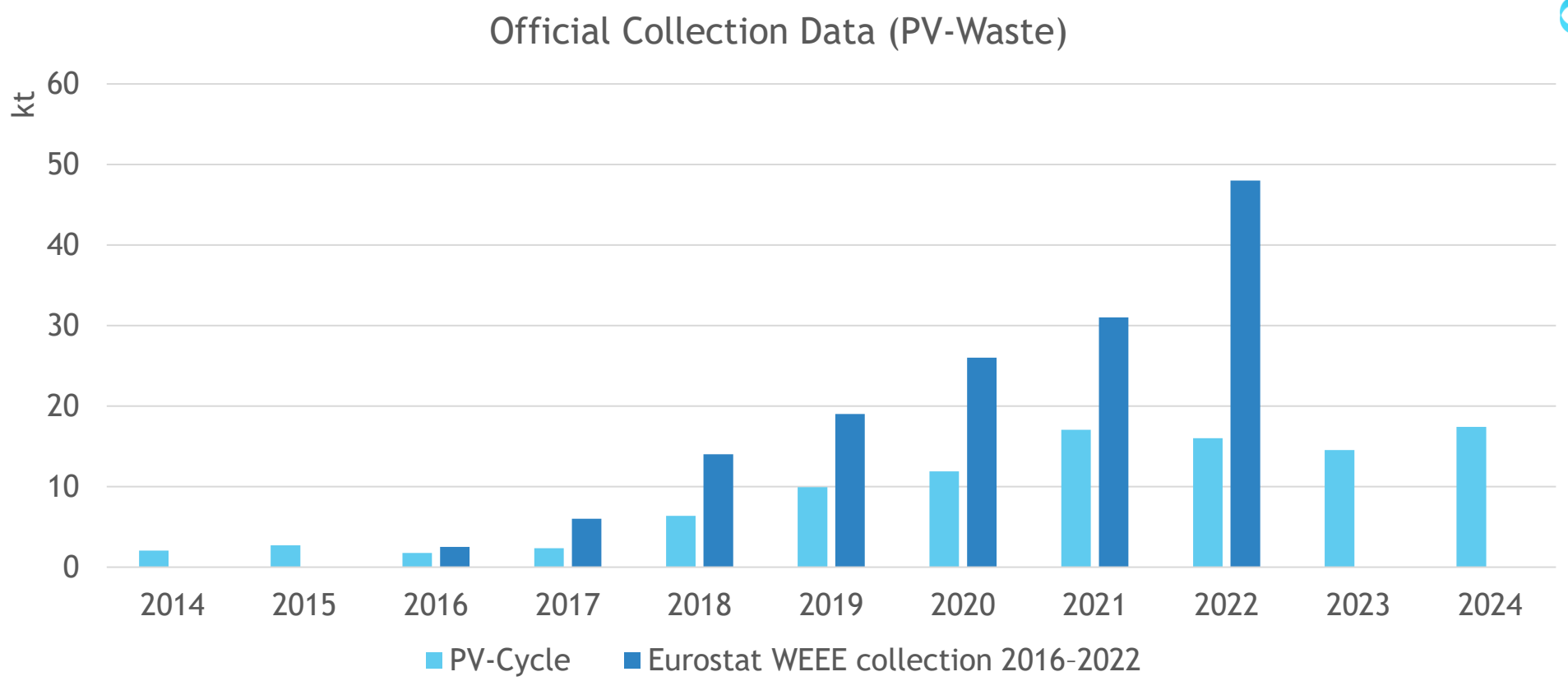
Automated Reuse & Recycling of PV Modules

Unlocking circularity in solar energy!

2nd cycle
for pv-modules



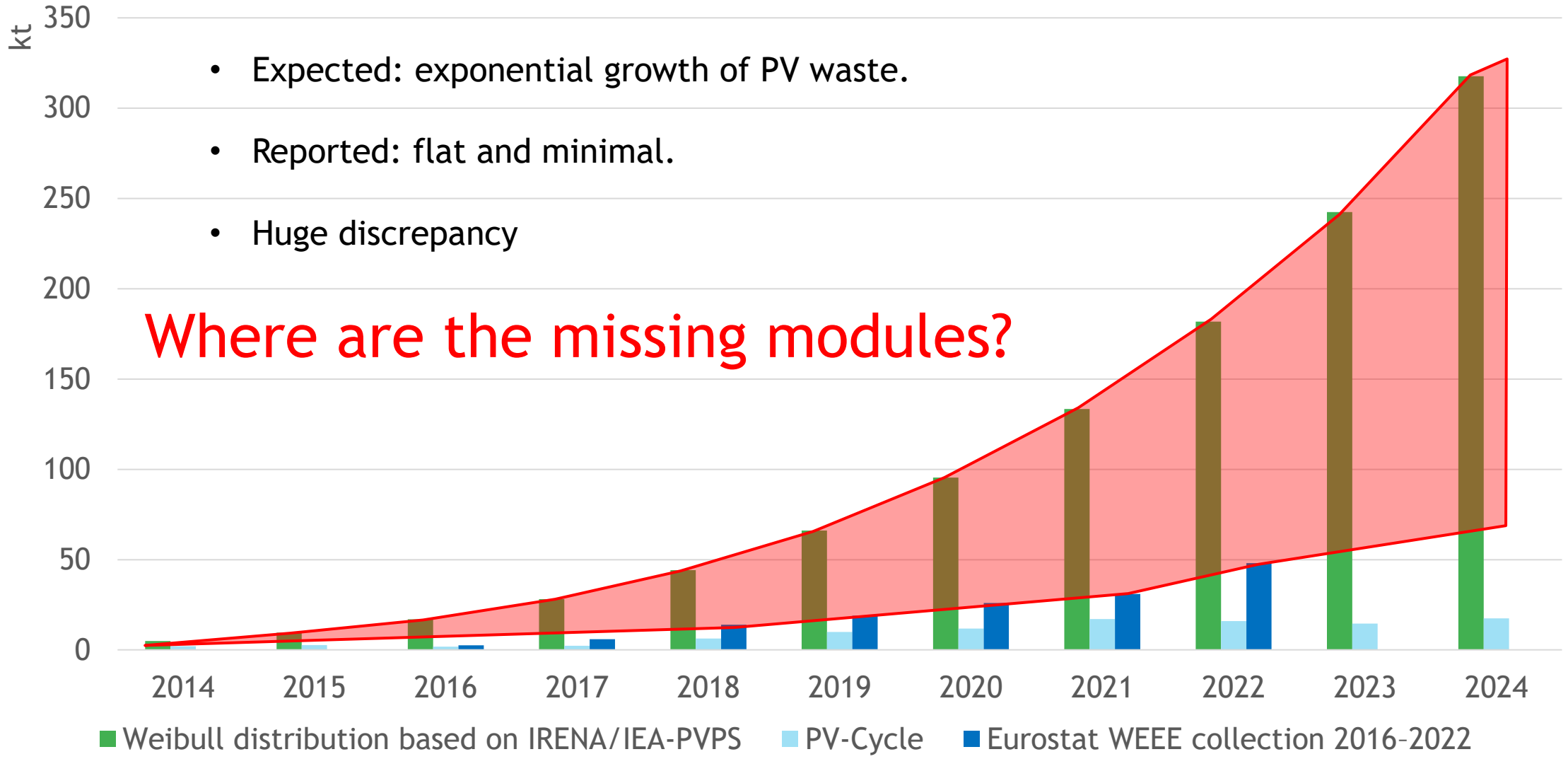
- PV Cycle: 17,5kt (2024), stagnating since 2021
- WEEE (Eurostat): 48 kt across 18 countries (2022)
- Oficial collection rates remain marginal

Sources: Eurostat (WEEE, 2022), PV Cycle Annual Report (2024)

Observed Collection Volumes vs. IRENA/IEA-PVPS Predictions

- Expected: exponential growth of PV waste.
- Reported: flat and minimal.
- Huge discrepancy

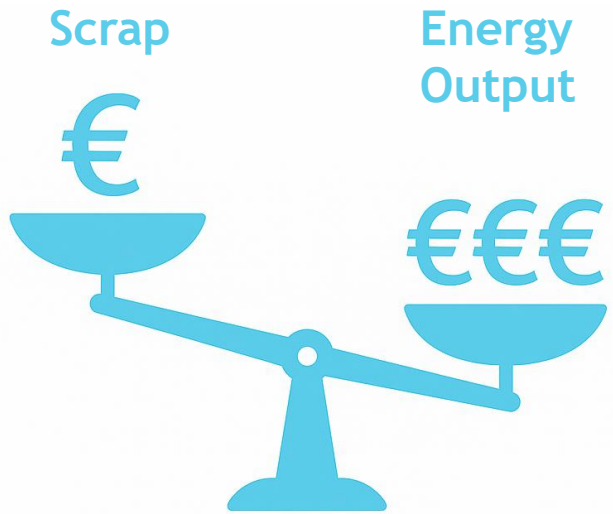
Where are the missing modules?



Source: Weibull distribution based on IRENA/IEA-PVPS End-of-Life Management: Solar Photovoltaic Panels (2016), positioned between early-loss and conservative scenario

Reuse as the Explanation?

- **First explanation: High durability** – PV modules last longer than expected
- PV Cycle Annual Report 2024: **Reuse** is the main reason for low collection.
  - **Our view:** Both are correct – long module lifetime inevitably leads to reuse
- Recycling requires subsidies → today not profitable.
- Reuse is different:
  - A functional module still has *residual energy value*.
  - Rest value is always higher than scrap value.



Reuse maximizes PV module lifetime – with environmental and economic benefits.

Source: https://pvcycle.org/annual-reports/2024-annual-report
Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, Article 4(1), *Official Journal of the European Union* L 312/3, 22.11.2008.

The Problem with Today‘s Reuse

Current Status of Reuse

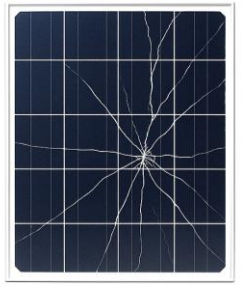
- Often no reliable testing → modules sold as *“**black box**”*
- Often **no traceability** or documentation
- Mixed with **illegal e-waste** exports
- Sellers remain **liable** in case of damage

Economic Pressure

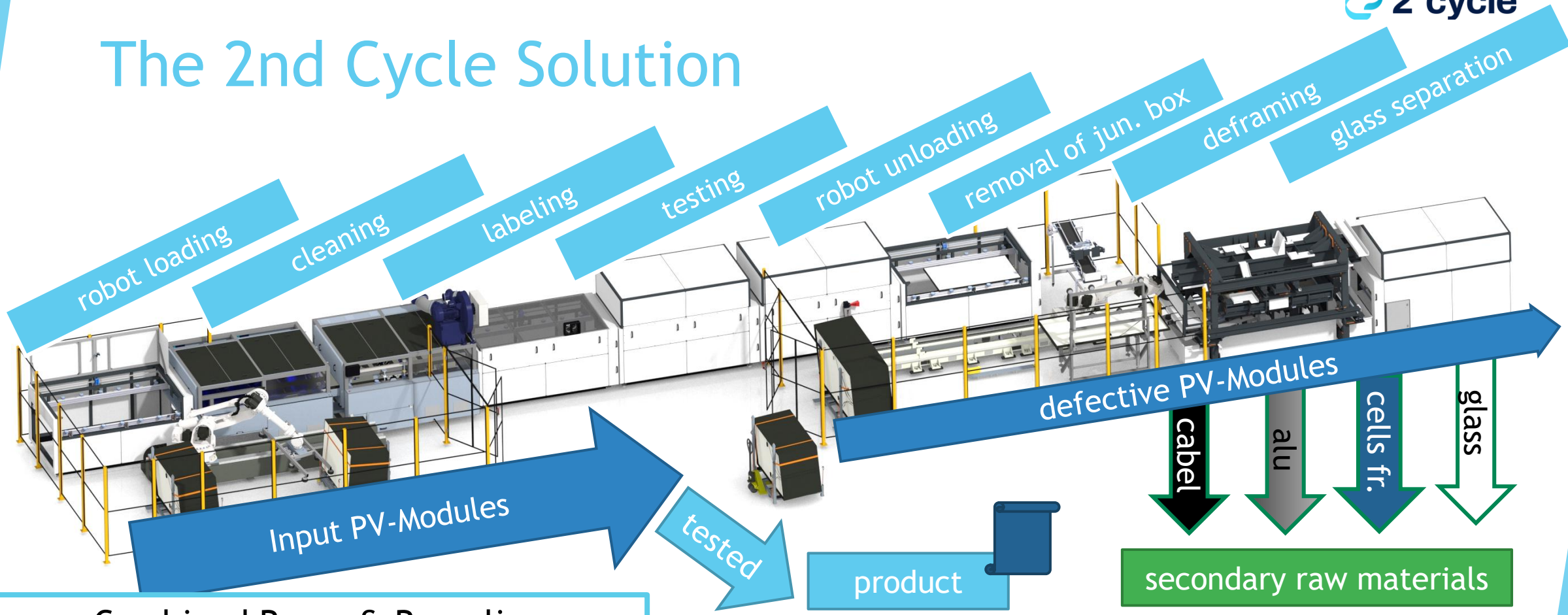
New modules at historically **low prices**
High-quality testing is **slow & costly**:

- Wet leakage ≈ 2 min/module.
- Visual & EL = expert evaluation.
- Documentation & logistics = cost drivers.

- Result: corners are cut → **safety & quality compromised**



The 2nd Cycle Solution



Combined Reuse & Recycling

- One integrated process, one logistics system (SolarBox).
- PV module identification & robotic handling.
- Same automation can be used for both reuse and recycling.

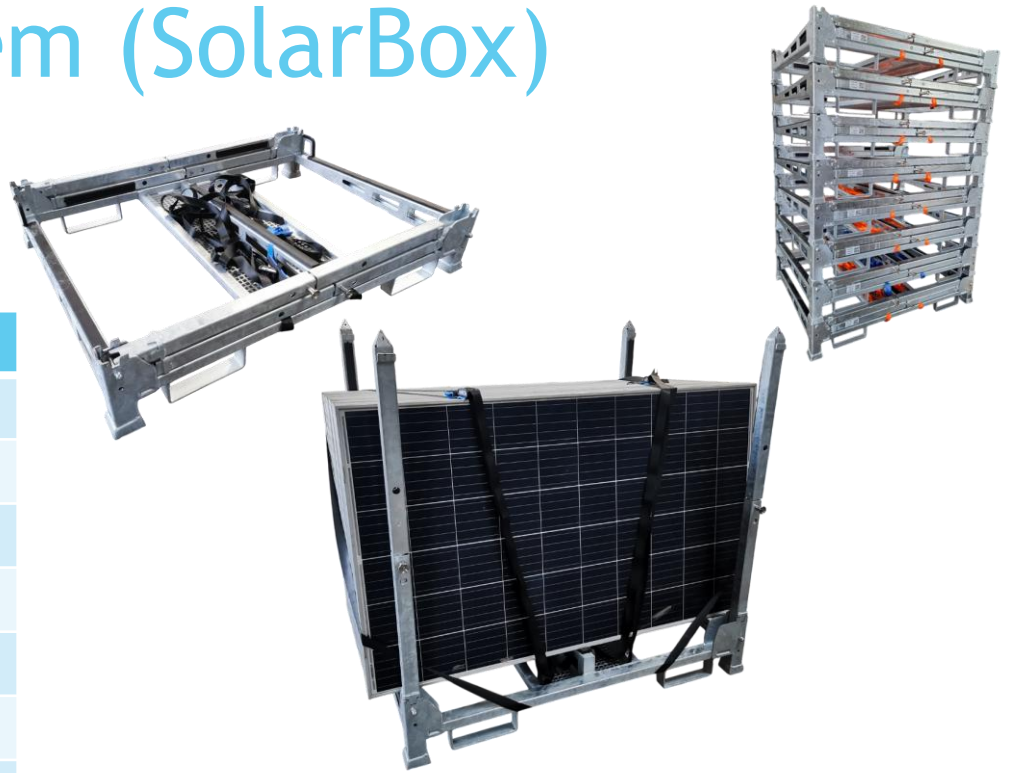
Synergies of Integration

- Shared logistics, handling & data infrastructure.
- Cleaning boosts quality for both reuse & recycling.
- Automated identification & testing → decision Reuse or Recycle.

The 2nd Cycle Logistic System (SolarBox)

The robust SolarBox is our logistical solution for the safe transport of PV modules:

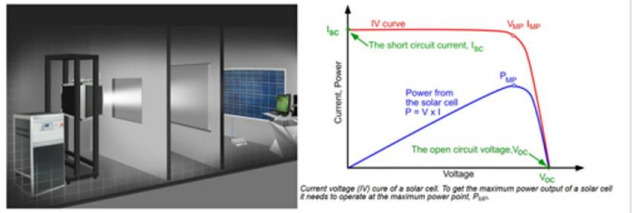
properties	Technical specifications
Stackability (loaded)	3 pieces on top of each other
Stackability (unloaded)	10 pieces on top of each other
net weight	58 kg
fastening	tension straps
Suitable PV module size (min.)	1430 x 890 mm
Suitable PV module size (max.)	2600 x 1600 mmm
Dimensions (folded)	1460 x 1130 x 270 mm
Automated robot unloading	yes
Gentle vertical storage	yes
GPS/tracking solution	optional



Testing Innovation of 2nd Cycle

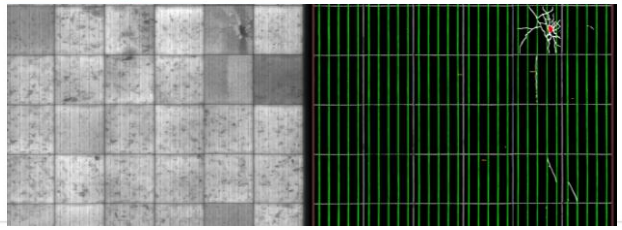
electrical contact

Flash-Test / dark I-V curve

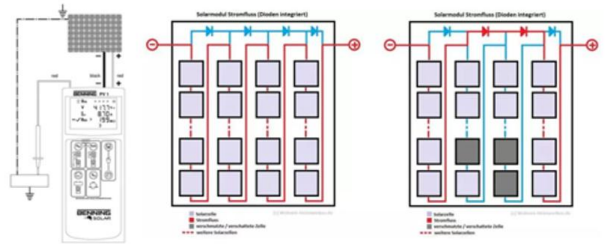


Current voltage (I/V) cure of a solar cell. To get the maximum power output of a solar cell it needs to operate at the maximum power point, P_{MP}.

EL-Test



Insulation Resistance Test / Bypass Diode Test / Frame Continuity Test



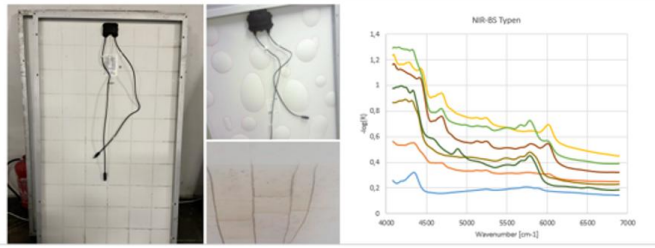
AI-powered data analysis

Test Protocol:

- Lifetime pred.
- Performance pred.
- Value assesment
- Material composition

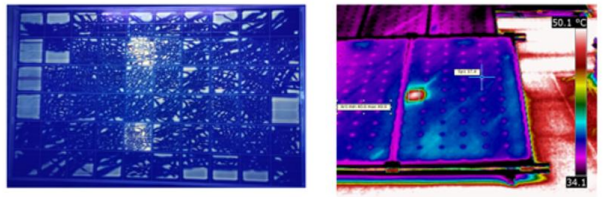
non electrical contact

NIR Spektroscopy

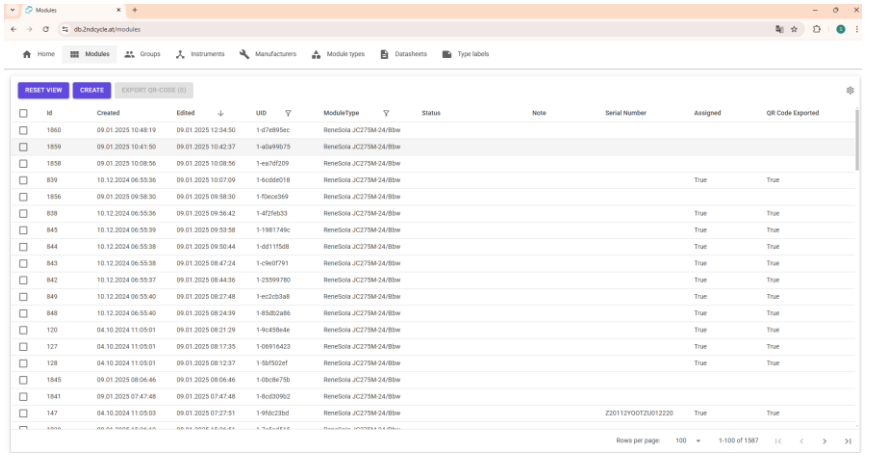


Visual Inspection

UV Fluorescence / Thermographie



Transparent & Traceable Test Reports



Module report

250919_143624_1-4565049f

prepared by
2nd Cycle FlexCo
Agathastraße 2-4 Top 4
3300 Amstetten

at:
2025-09-19 14:36:24

Manufacturer
TrinaSolar

Model
TSM-395 DE09.08

Serial number
K03210400452529

UID
1-4565049f

Overall rating	Passed

Overview

Performance measurement	Result [%] acc. internal testing specification
Relative power at MPP	Limit 96

Bypass diode test	Result [%] with threshold from EN61215-2 (MQT 18.2 - Method B)
Flow voltage @ 1A	Limit 94

Dark IV test	Result [%] acc. internal testing specification
Float voltage @ Isc	Limit 95

Visual inspection front	Result [%] acc. internal testing specification
Safety	Limit 100
Quality	Limit 100

Visual inspection back	Result [%] acc. internal testing specification
Safety	Limit 100
Quality	Limit 100

EL inspection	Result [%] acc. internal testing specification
Safety	Limit 100
Quality	Limit 99

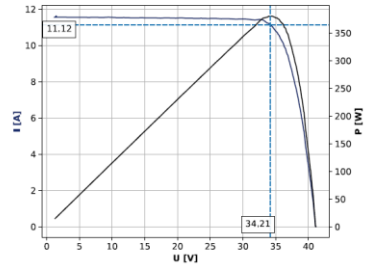
Module information

Manufacturer	TrinaSolar
Model	TSM-395 DE09.08
Serial number	K03210400452529
Maximum power	395 W
Open circuit voltage	41.0 V
Short circuit current	12.21 A
Dimensions	1754 x 1096 x 30 mm
Weight	21.0 kg
Number of Cells	120
Module Efficiency	20.5 %
Maximum System Voltage	1500.0 VDC

Front view

Back view

Performance measurement



Electrical characteristics (STC)	
Maximum power	380W
MPP-voltage	34.2V
MPP-current	11.12A
Open circuit voltage	41.1V
Short circuit current	11.60A

STC: irradiance 1000W/m², Cell Temperature 25°C, Air Mass 1.5

	Measuring result [%] acc. internal testing specification
Relative power at MPP	Limit 96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Let’s Build Circularity into Solar – Together

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for pv-modules

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