Cost competitiveness of US Solar Manufacturing

Solar – Made in the USA

Prof. Dr. Peter Fath
Founder & CEO - RCT Group
September 3 2025

RCT Solutions GmbH

a member of RCT Group

One-Stop Renewable Solutions Partner

An Integrated Renewable Ecosystem

RCT Solutions

2012
Founded

26 Countries
Operating Worldwide

73 GW Engineered
Integrated PV

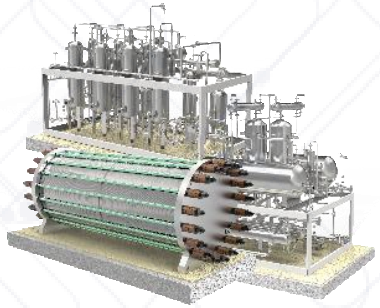
RCT Power

5th Largest ESS provider
Bloomberg Tier 1 listed

>14.5 GWh (6 GWh USA)
Total shipments

Best Storage
Awarded 6 years in a row

RCT Hydrogen



>70 MW
Globally deployed HGS

>1.000 MW
Manufacturing Capacity

Modular Design
100 kW – 20 MW flexibility

RCT Modules

67 Projects
Field-proven reliability

30 Years
Engineering compatibility

3 Manufacturers
RCT-engineered projects

RCT Financial Advisory

2025
Founded

ECA-Backed Financing
Securing longer loans

Clean-Energy Mandate
Solar, storage, hydrogen

Global top Brand of Renewable Solutions

Headquarter
Germany

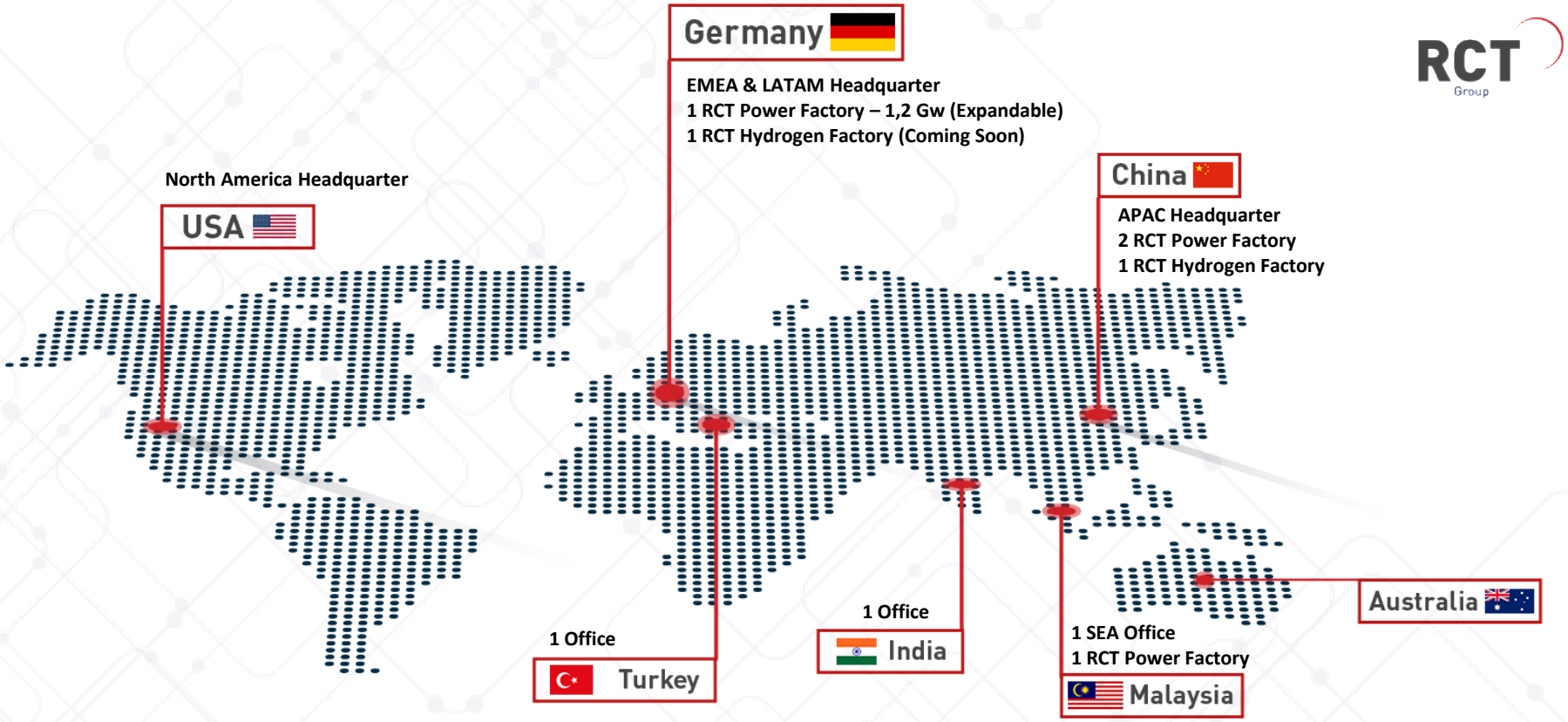
Employees
650+

Manufacturing
Germany, China, Malaysia

Cumulative Shipment
14.5GWh

27 Countries
Active services

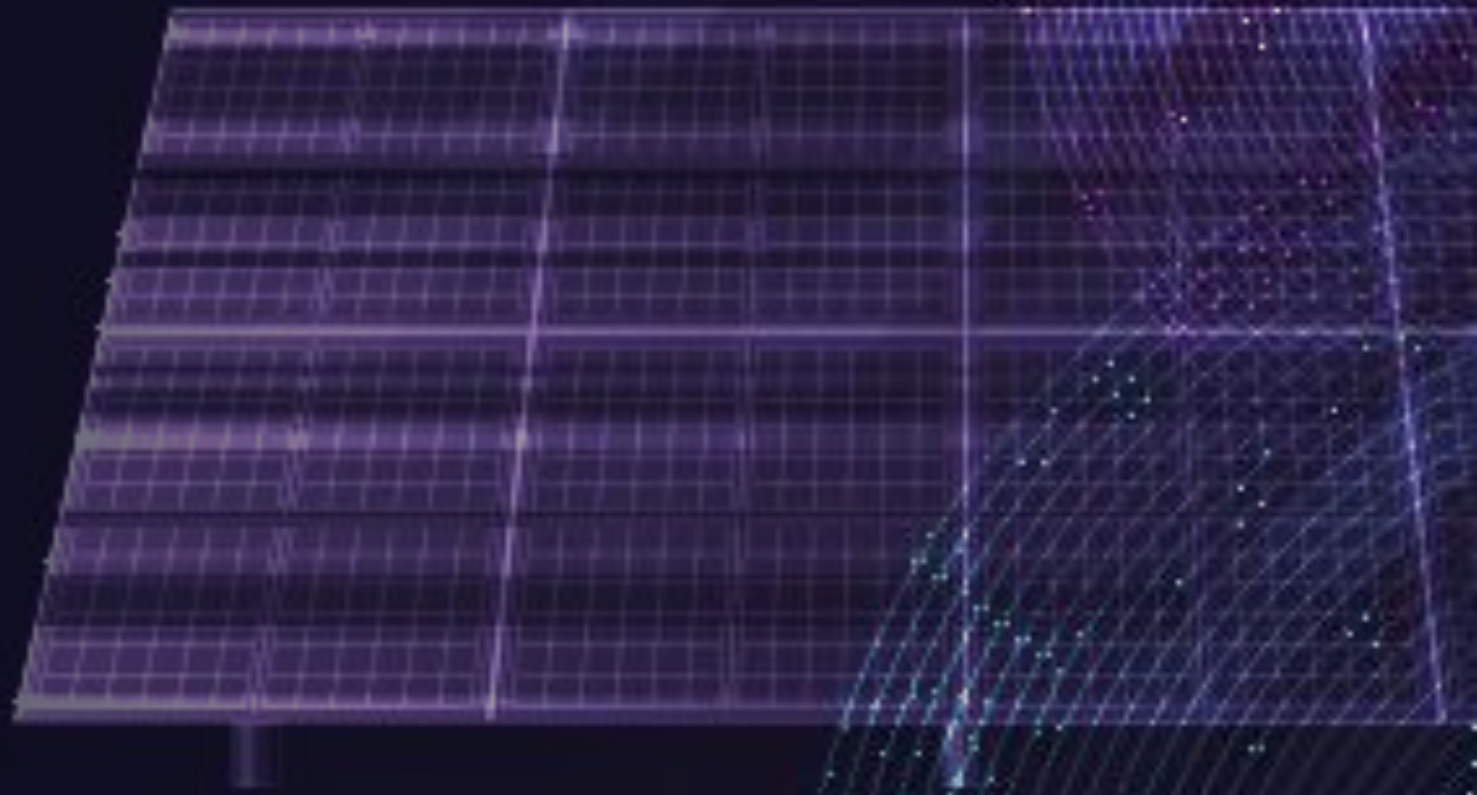
73 GW
Executed PV engineering



Hochvolttechnologie vom Bodensee

Technology and Design Made in Germany

Agenda



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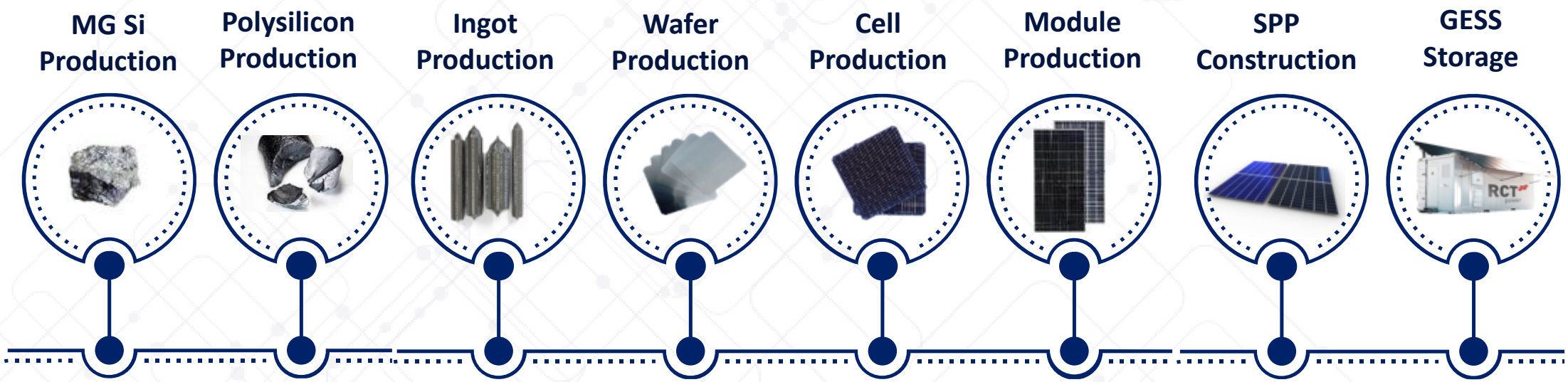
RCT solutions

Agenda

1. **Six factors for a sustainable domestic PV Ecosystem / Worldwide status**
2. **Post-IRA Era**
3. **Cost competitiveness of the USA**
4. **Does it still make sense to invest to solar in the USA?**
5. **Worldwide examples**

Vertical & Horizontal full Integration
into Giga-scale PV



- Quartz
- Prebaked electrode
- Coal

- Graphite chuck
- Gases (HCl, N_2, H_2, Cl_2)

- Hot zone
- Crucible
- Ar

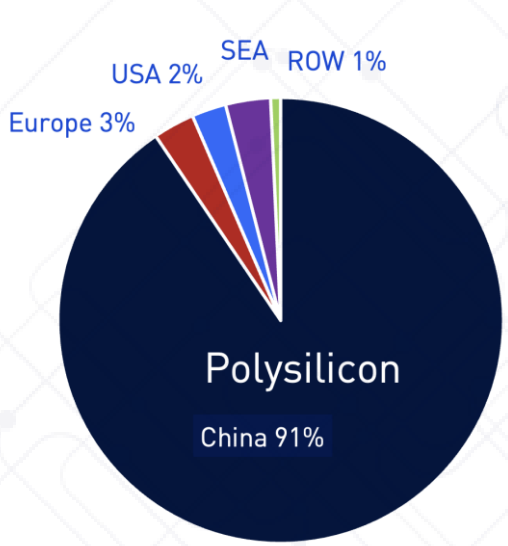
- Diamond wire

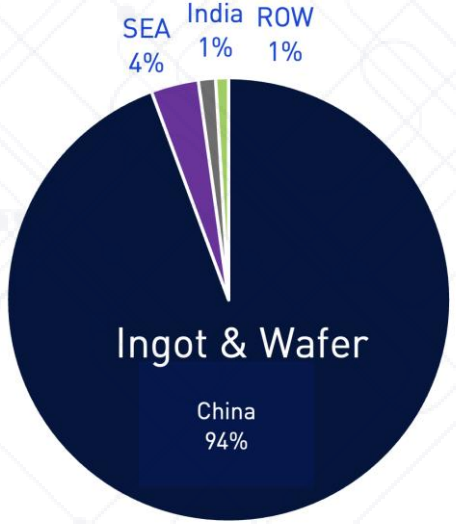
- Ag paste
- Screens
- Chemicals
- Gases

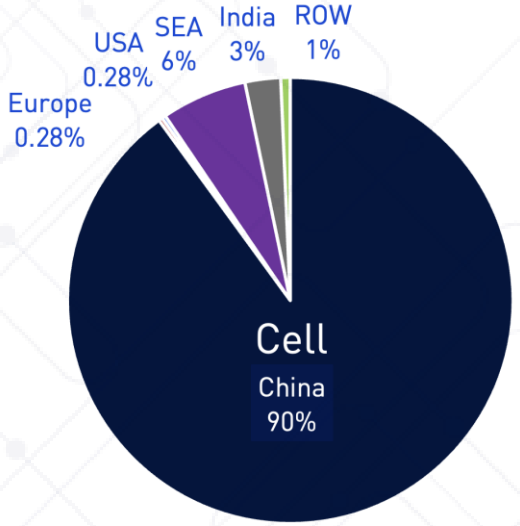
- Glass
- Encapsulation material
- Al frames
- Junction box& ribbons etc.

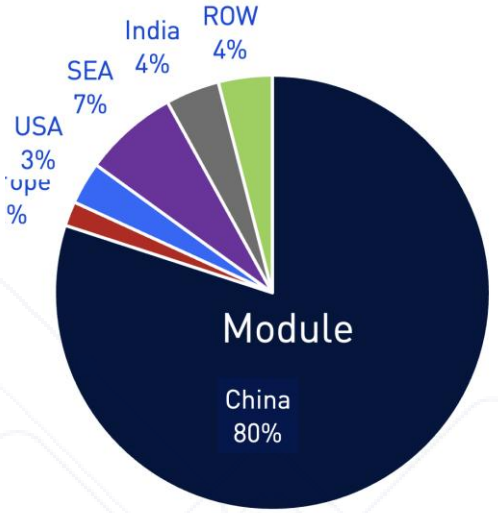
Worldwide PV Production
Current Status

Integrated Manufacturing Along the Value Chain









Six Factors affecting the domestic PV Ecosystem in the USA

Capital Bottlenecks

High rates and risk premiums keep domestic manufacturing finance tight.

Grid & Permitting Drag

Slow, inconsistent interconnection and permits delay projects and inflate soft costs.

Workforce Crunch

Shortages of skilled factory and field labor raise wages and stretch timelines.

Fragile Supply Chain

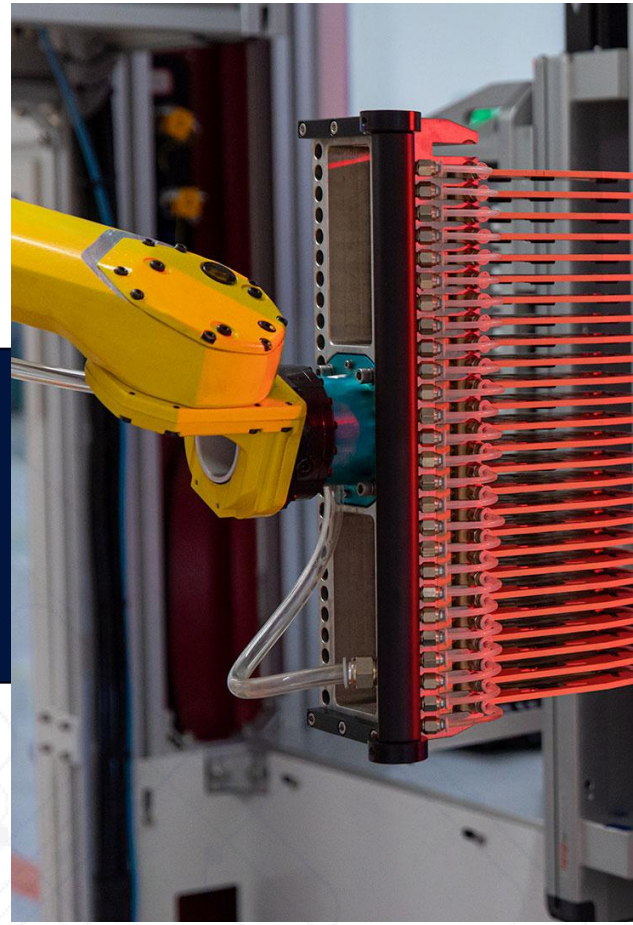
Gaps from raw materials to components increase cost, risk, and lead times.

Equipment Support Gap (Non-PRC)

Limited incentives for allied toolmakers hinder competitive, non-PRC capacity.

Policy Whiplash

Unpredictable federal/state rules and trade actions undermine planning and investment.



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Domestic Investment in PV Manufacturing

Post-IRA Era

- $45.8B announced since passage of IRA, estimated to create 58,700 manufacturing jobs
- $9.1B operational, 18,300 jobs created
- $15.6B under construction (12,950 jobs)
- $21.1B and 27,460 jobs at risk

Imbalanced Investments in Supply Chain

Module assembly

- Capacity (14GW$_{dc}$ CdTe, > 50GW$_{dc}$ c-Si) exceeds 2025 market demand (≈ 40-45GW$_{dc}$) even wo imports (≈ 53GW 6/24-5/25) and inventory
- Lowest capex requirements, easy to move
- Equipment almost exclusively from Chinese vendors
- Shakeout imminent

Polysilicon

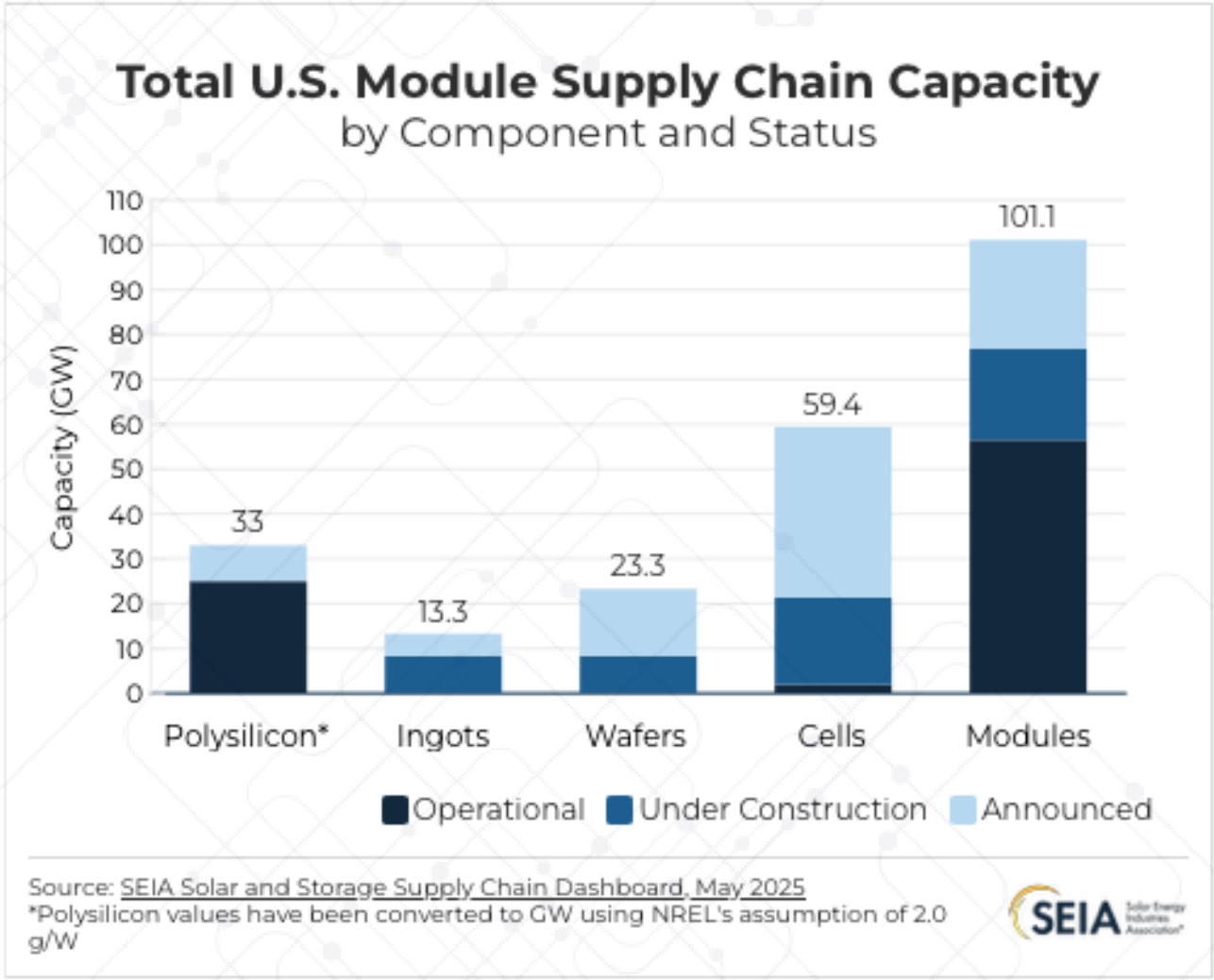
- Capacity competes with SEMI (ASP & expansion)

Solar Cells

- 2GW$_{dc}$ PERC operational
- Realistic +3GW$_{dc}$ PERC and +1GW$_{dc}$ TOPCon operational 2025
- Everything else at risk due to lack of access to capital
- TOPCon IP challenge
- Some select western equipment

Ingot/wafer

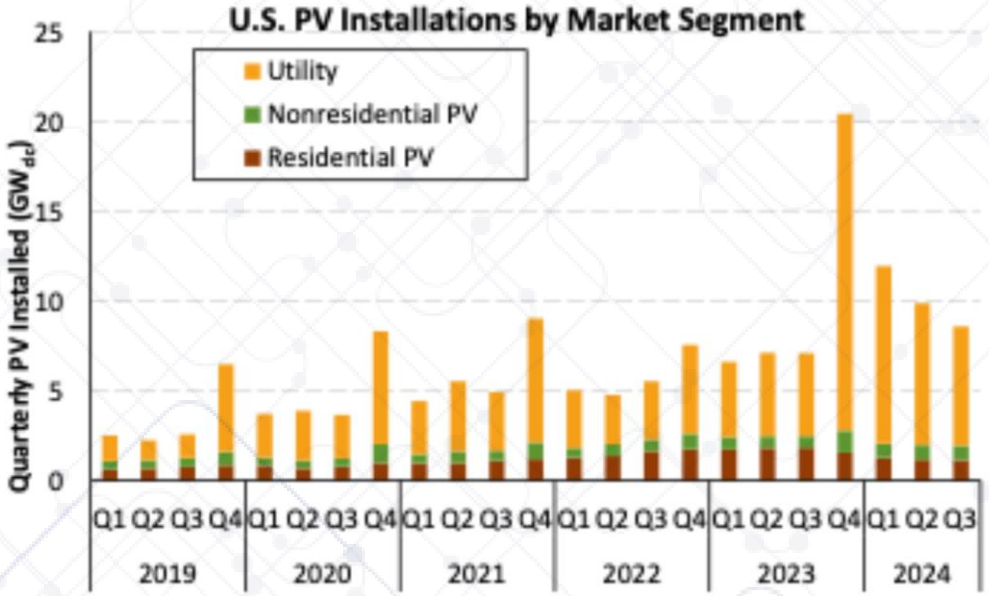
- ≈ 7GW$_{dc}$ nameplate capacity to come online 2025
  - Corning to start manufacturing Q3'25
  - Qcells to start production H2'25
- Rest at risk due to lack of financing despite CHIPS Act applicability

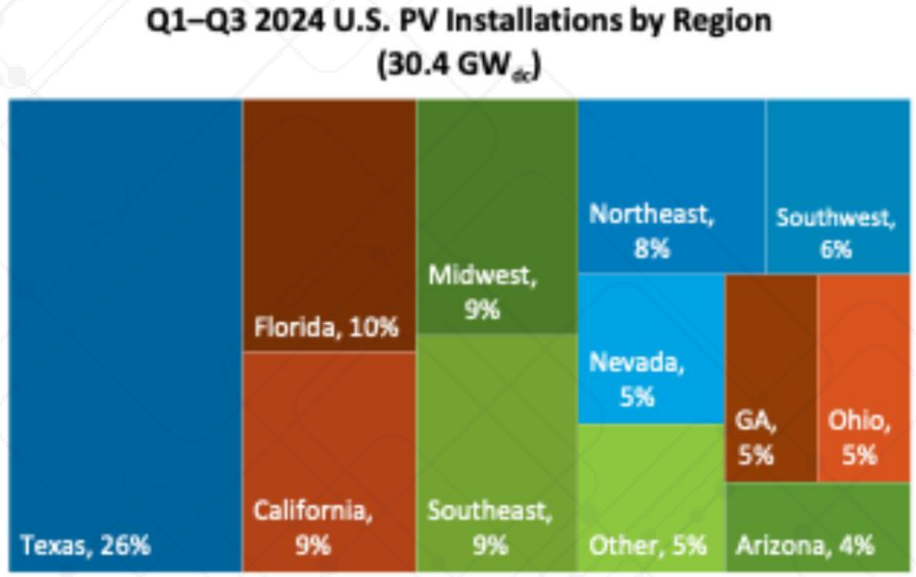


US Market Installations
Phaseout and Avoidance of/Safe Harboring for FEOC Restrictions?

Domestic PV installations between 2019 to 2024

- Wood Mac and SEIA report 30.4GW$_{dc}$ for Q1-Q3'24 (EIA 21GW$_{ac}$ ≈ 26.25GW$_{dc}$ at DC/AC ratio of 1.25)
- Preliminary total for 2024 ≈ 44GW$_{dc}$
- UPV increased 81% y/y, C&I 20%, while resi. shrank by ≈ 33%
- Preliminary data from SEIA for Q1'25 10.8GW$_{dc}$
- IEA forecast for 2025 32.5GW$_{ac}$ (≈ 40.6GW$_{dc}$ at DC/AC ratio of 1.25)





Data: Wood Mackenzie/SEIA, U.S. Solar Market Insight: Q4, 2024

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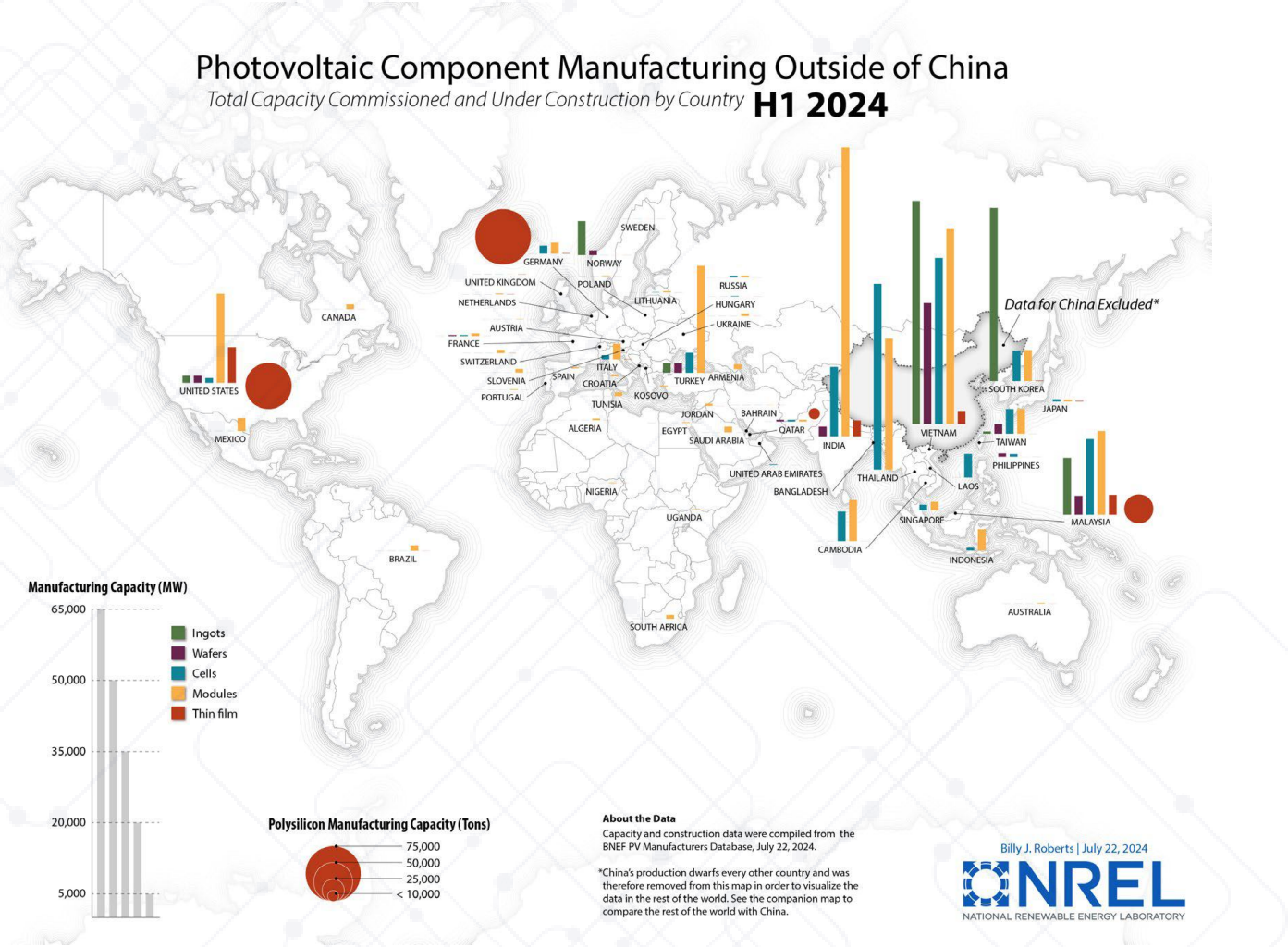
Comparative Global PV Manufacturing cost and pricing
Our recent Assessment

- Production locations for PV manufacturing are diversifying globally
- Incentive programs available in India, USA, Turkey and in-sight for Europe

Question of investors and governments in PV manufacturing

- Which are the main cost drivers at each production stage along the PV value chain?
- What are the cost differences for PV production in different global regions?



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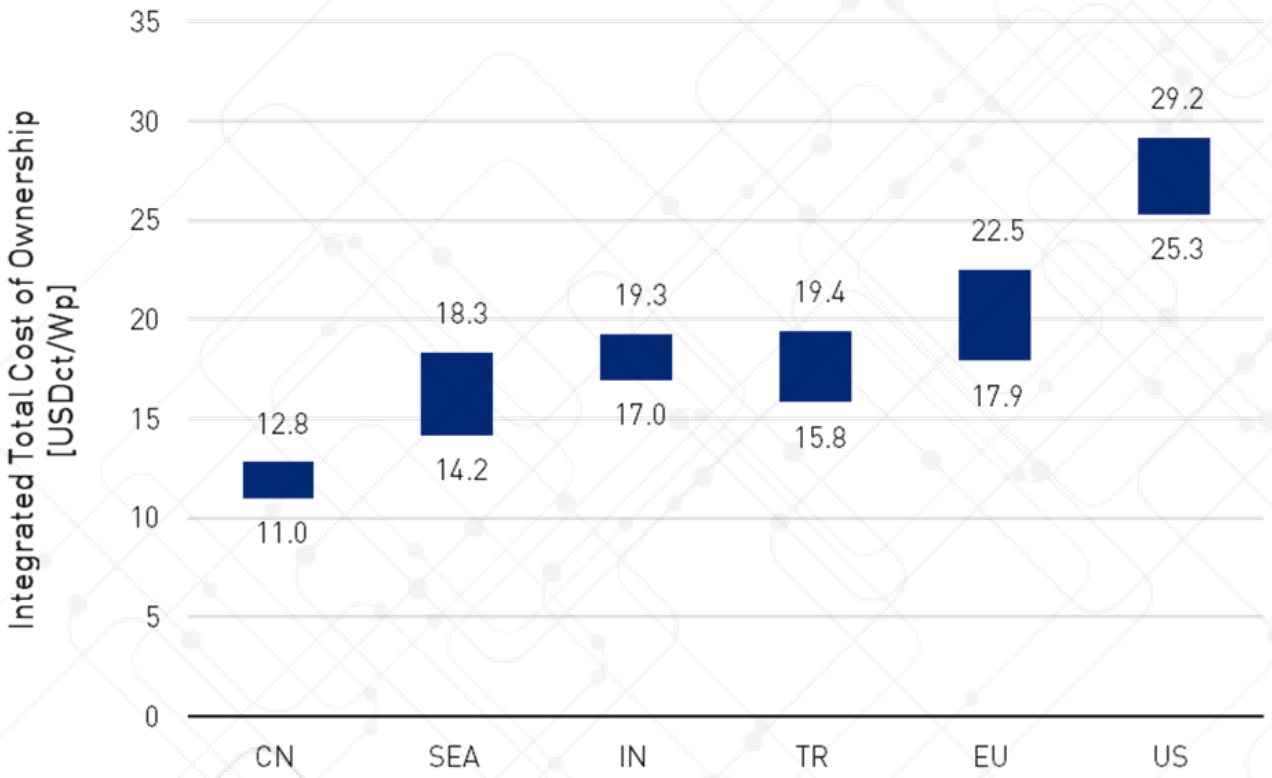
Comparative Global PV Manufacturing Cost and Pricing
Impact on “fully-local” in EU/U.S. manufactured TOPCon PV Module



MSP difference for “fully-local” TOPCon PV Module:
In Southeast Asia nearly similar, India slightly higher MSP.

Difference in Europe & US in comparison to China:

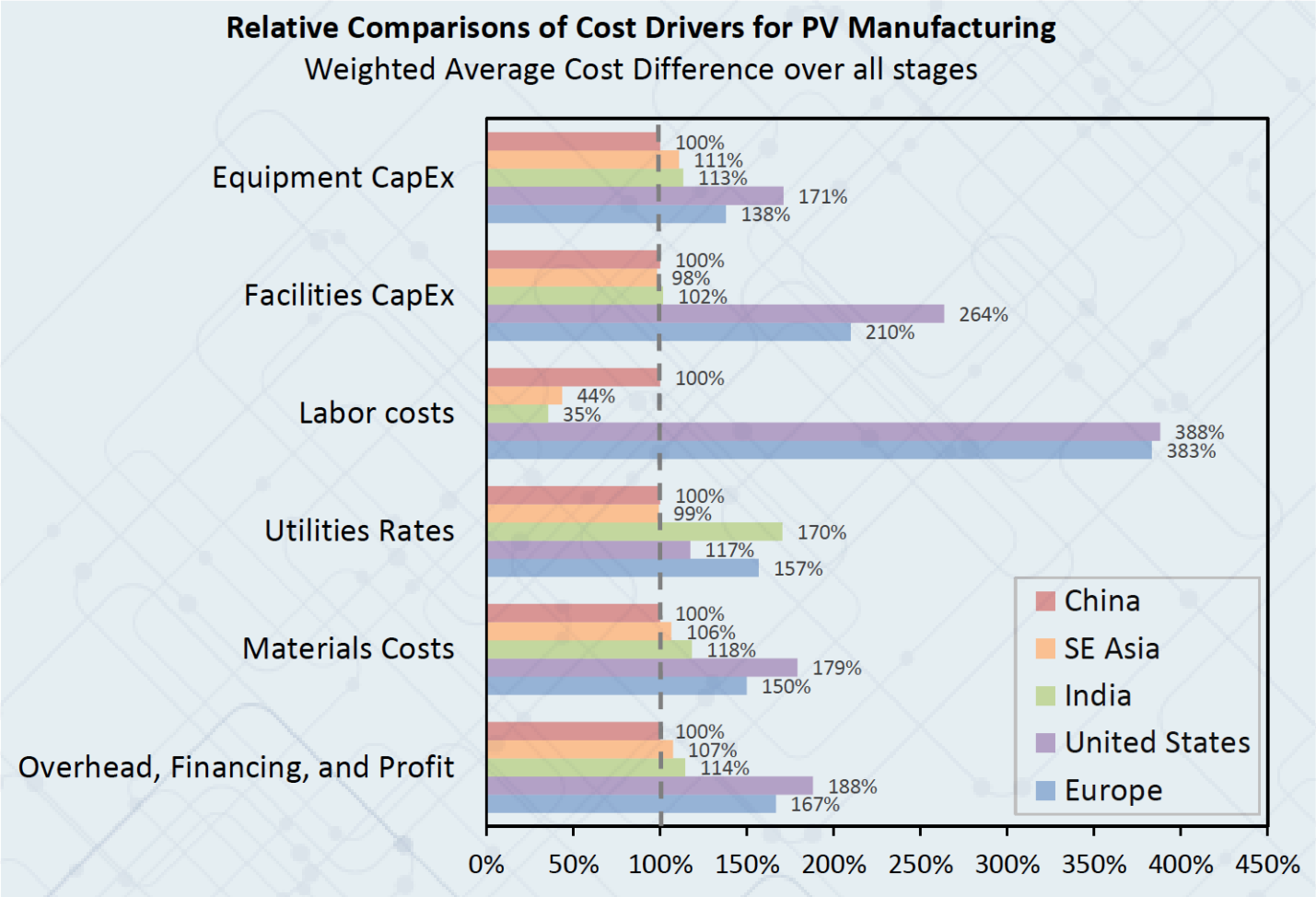
Ingot-to-Wafer (ingot + wafer):
- EU: +1.4 / +2.2 ¢ct/Wp
- US: +1.3 / +1.9 ¢ct/Wp

Ingot-to-Cell (ingot + wafer + cell):
- EU: +2.6 / +4.0 ¢ct/Wp
- US: +4.9 / +6.2 ¢ct/Wp

Ingot-to-Module (cell + module):
- EU: +5.5 / +6.2 ¢ct/Wp
- US: +11.2 / +12.7 ¢ct/Wp

→ Main cost differences for Materials and Labor.

Comparative Global PV Manufacturing Cost and Pricing
Relative Comparisons of Cost Drivers for PV Manufacturing



Key Cost Drivers in Europe and US in comparison to China

Equipment CAPEX
- 40-70% higher (w/ Western Equipment)

Building and Facility CAPEX
- 2.1-2.6 x higher construction costs

Labor costs
- 3-4 x higher: wages & working hours

Utility (Electricity, Water, …)
- 20-60% higher

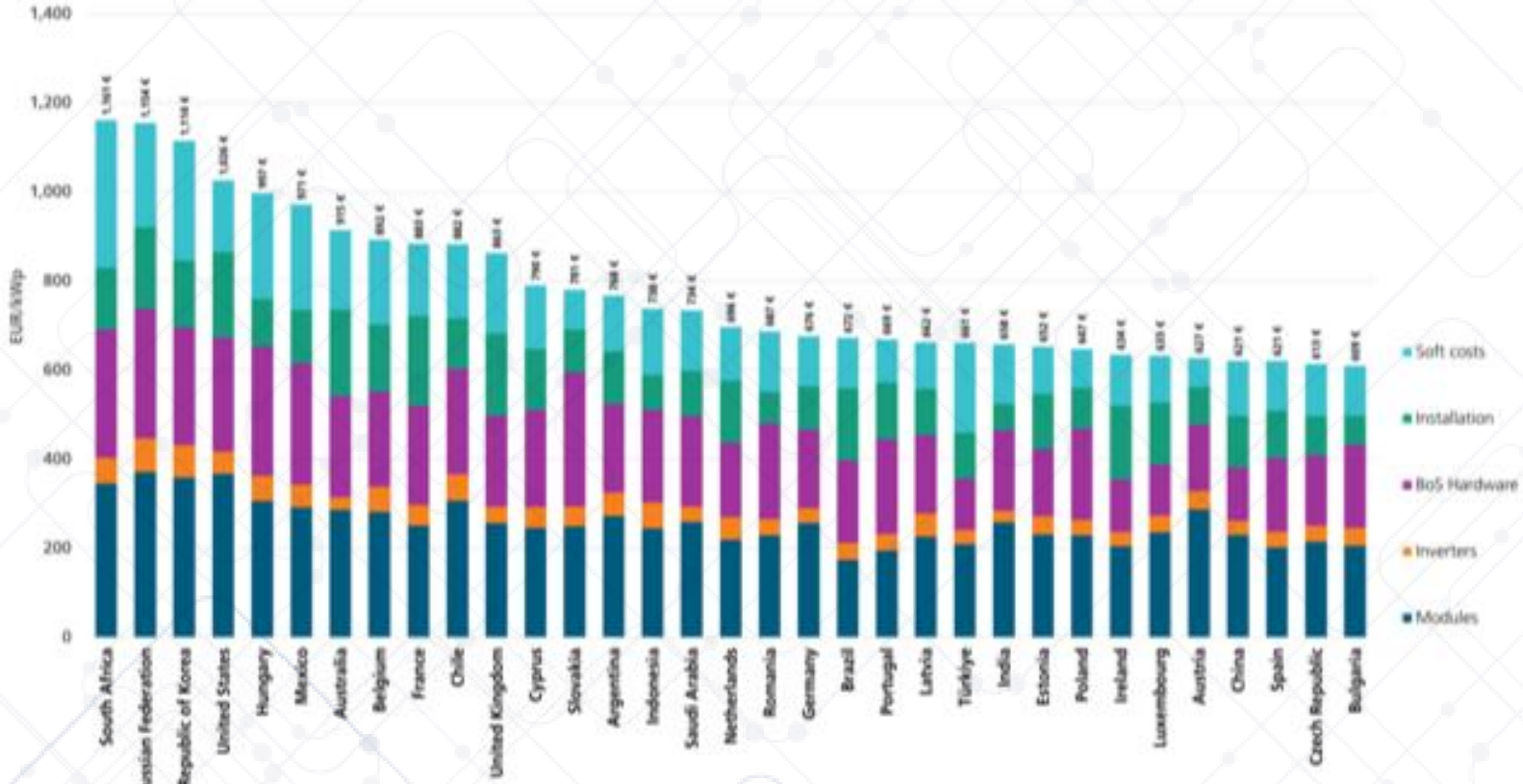
Material Costs:
- 50-80% higher (with local BOM)

Overhead, Financing, and Profit
- Same margin adding more to MSP

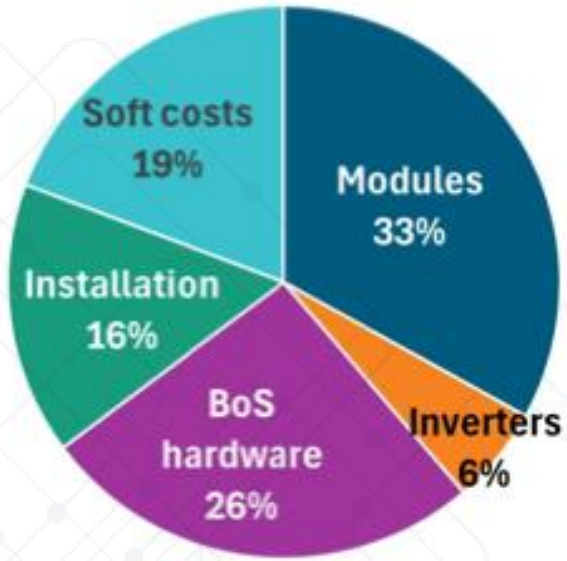
System Cost Competitiveness
Breakdown by Components

Utility-scale, total installed PV system cost by country in 2023

- U.S. above average component costs and high soft costs



Breakdown of Cost Components
(average of available country data):



Domestic PV
System Price Stagnation

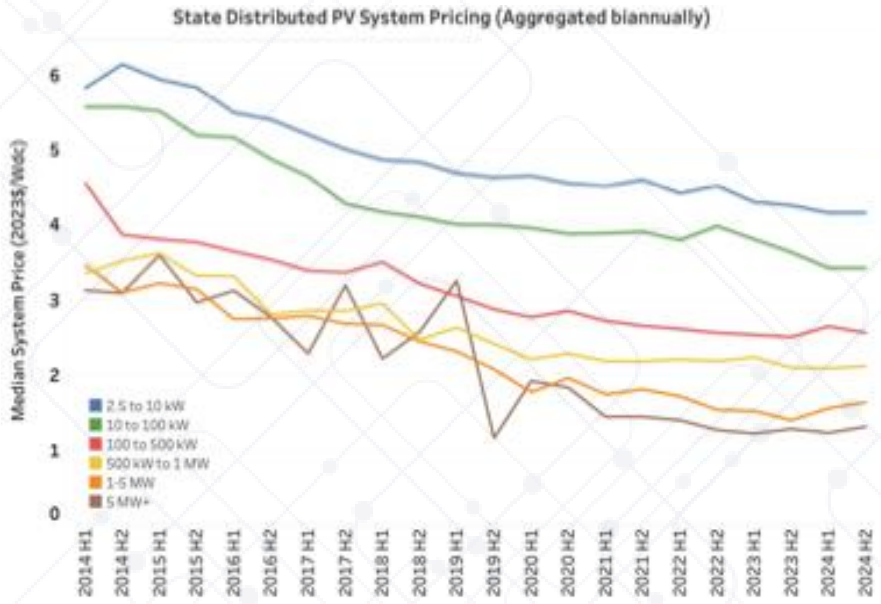
Domestic PV system price regression slowing since passage of IRA

- 201 tariffs and AD/CVD impacting imported module and cell* pricing
- 2024 imports 54.3GW$_{dc}$ modules, 13.89GW$_{dc}$ cells*

Current module pricing (July, OPIS)

- Imports ≈ ¢25/W (SEA), ≈ ¢29/W (India)
- U.S. assembled not meeting DC ¢26-33/W
- U.S. meeting DC ≈ ¢40-50/W

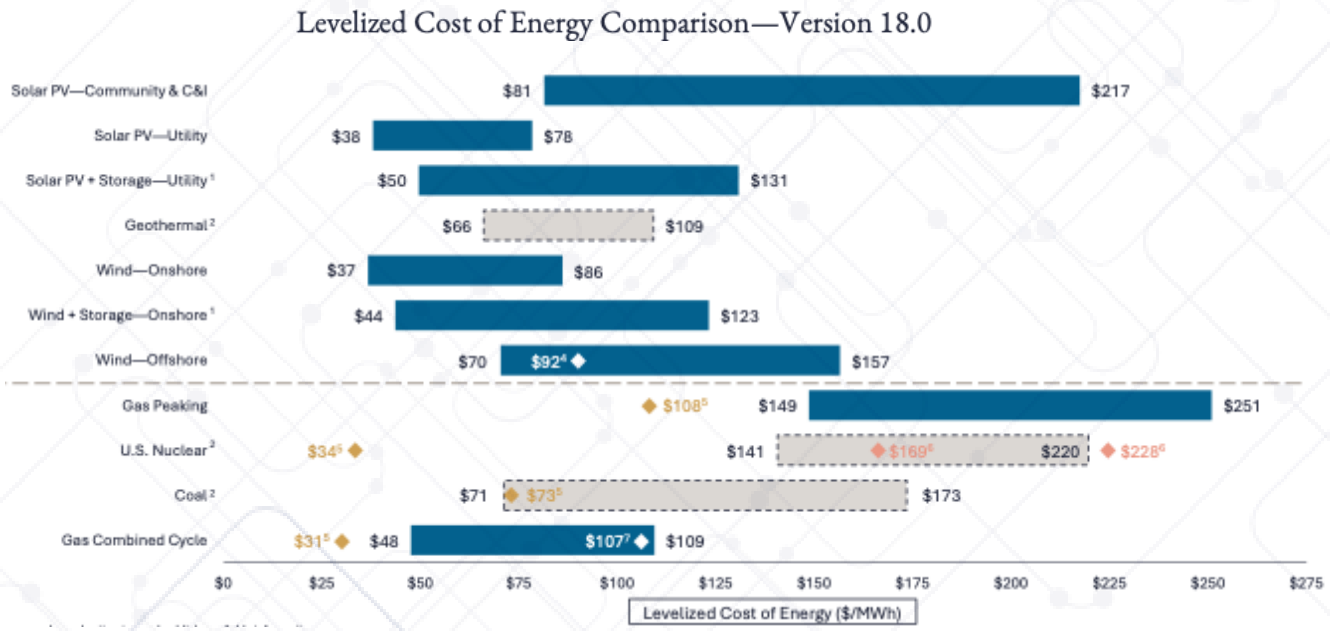
System Size	Price H2 2024 ($/W$_{dc}$)	Change 2023–2024
2.5–10 kW$_{dc}$	$4.15	–2%
10–100 kW$_{dc}$	$3.42	–6%
100–500 kW$_{dc}$	$2.55	+2%
0.5–1 MW$_{dc}$	$2.11	+1%
1–5 MW$_{dc}$	$1.63	+17%
5 MW$_{dc}$+	$1.30	+2%

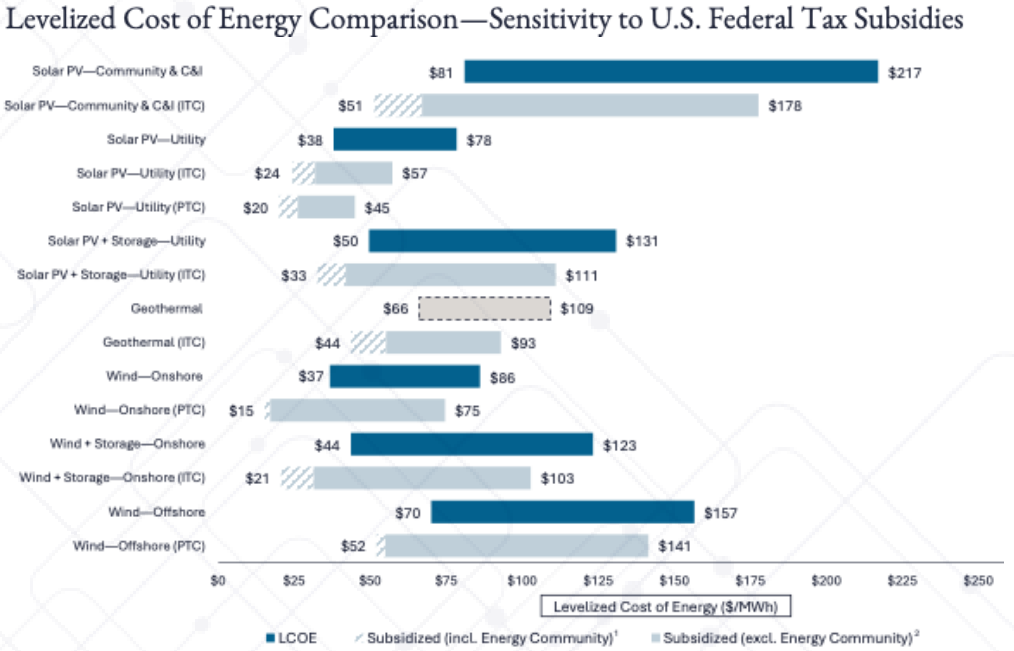


Domestic PV LCOE Competitiveness

LCOE comparison to other RE and conventional energy technologies

- Competitive LCOE (and PV+ESS most competitive installation time)
- IRA ITC, PTC, and Energy Community adders make PV significantly more attractive—the future of these IRA incentives is at present uncertain





Data: Lazard: Levelized Cost of Energy, June 2025

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Does is still make sence to invest?

Yes! And here’s how!

Current Federal U.S. Policy Landscape
‘nothing is certain but death and taxes’ BUT

Trade & Policy Measures	Supply Chain Segment			
	Poly	c-Si Wafers	c-Si Cells	Modules
AD/CVD Duties (PRC, Taiwan)			X	X
AD/CVD Circumvention Duties			X	X
AD/CVD Duties (SE Asia)			X	X
Section 201 Tariffs				X
Section 301 Tariffs (PRC)	X	X	X	X
45X (MPTC)º	X	X	X	X
48C*	X		X	X
48D (CHIPS)		X		
Transferability (45X)	X	X	X	X
Domestic Content Bonus			X	X
BABA Requirements			X	X
Loan Guarantees	X		X	X
RD&D Support+				
FEOC Restrictions	X	X	X	X

º can stack
* closed, unclear if a new round would open if allocated $10B are not used
+ unclear if new projects will be funded, Administration’s 2026 SETO request at $0, House Mark $115M

Downstream Incentives

- 25D resi. ITC
- 45Y PTC
- 48E ITC
- Transferability (also for 45X)

Various state-level policies either supporting or penalizing solar (both DG and UPV)

Local opposition towards DG, community solar, and UPV—perceived land conflict with agriculture but not with golf courses

- U.S. has 16,297 golf courses covering 8,014km^2
- At 50% coverage this would accommodate the current installed PV capacity on only 3,000 of the courses

Data: Environ. Res. Commun. 7 (2025) 021012

Current Federal U.S. Policy Landscape

Several states meets CO_2 goals despite hostile federal policy

- **7/1 Section 232 case Commerce investigation for polysilicon and derivatives**
  - Unclear if PV will be viewed as a national security element, and if so, how far down the supply chain remedies would go
- **7/8 announcement planning 50% tariffs on copper as of 8/1 to match aluminum and steel**
- **Country-specific tariffs of importance to PV**
  - EU Trump threatens 30% starting 8/1, EU signalled acceptance of 10% if certain sectors are exempt
  - ROK & Japan 25% (as of 7/7)
  - India, no Trump letter yet
- **7/17 AD/CVD investigation (Solar 4) Indonesia, Laos, and India; if positive ≈ summer 2026**
- **Potential "Blue Wafer Debacle" following recent CBP ruling**
- **Counterproductive actions by administration scaling back on energy efficiency standards & regulations**
- **Solar projects on public lands need several new political reviews at Department of the Interior**
- **FY25 SETO spending cut to $42M; FY26 appropriations (House) $115M:**
  - Direction: $9M CdTe, $10M R&D and $15M mfg. PVSK, $5M recycling

Impact of IRA on RE Workforce

- ≈ 80% of the private investment announcements spurred by IRA occurred in Republican districts
- Treasury stated IRA investments are expected to support 1.5 million jobs over the next decade, based on analysis by **the Labour Energy Partnership**

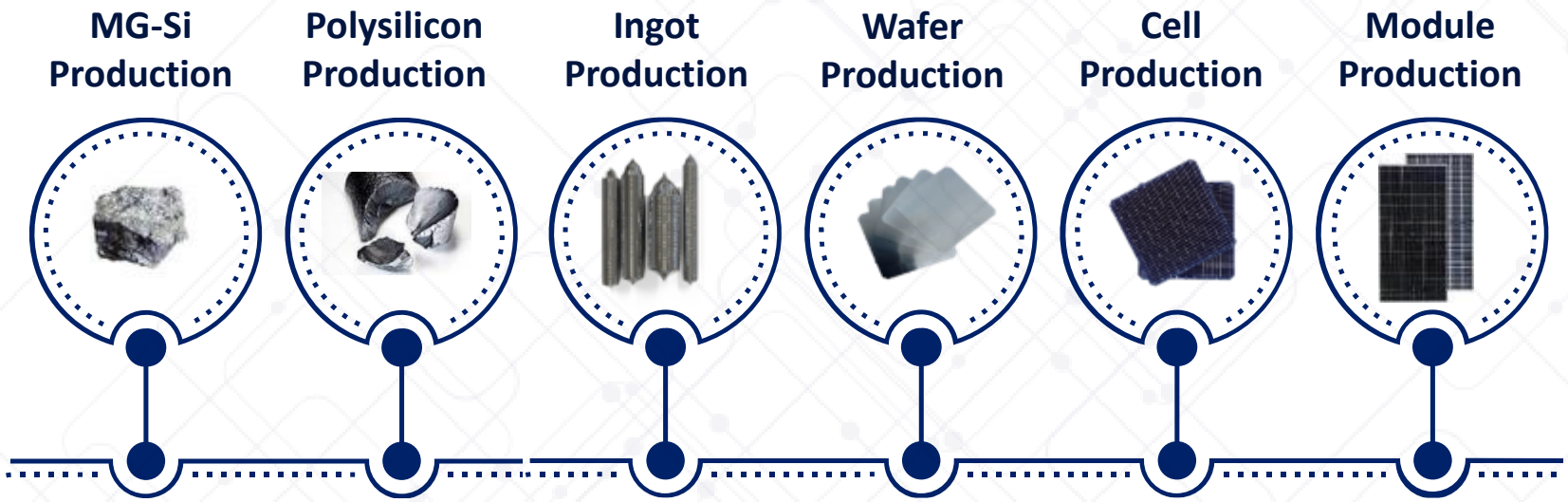
Projects By Congressional District

Party	Projects	Investments	Jobs
Republican	224	$109,630,229,000	83,115
Democratic	118	$19,486,500,000	28,834
Undefined	20	$3,031,800,000	4,510

Source: E2

- **Other**
  - AMC Upskill Prize Round 2 ($7.75M) still up in the air
  - 7/8 Supreme Court lifts ban on 107,000 federal workforce reduction plans; DOE included in list of Administration's priority
  - FY26 $0 budget request for SETO & 7/17 House Committee on Appropriations proposed $1.85B (38%) cut to EERE
  - 1/20/2025 reinstating EO 13957: Schedule F

Domestic Availability of Input Materials



*Available

*Currently no domestic supply but available from allied trade partners

+No domestic availability for rolled, c-Si front and back glass, low-Fe float available, glass for TF PV available to meet 100% of demand

- Quartz
- Prebaked electrode
- Coal

- Graphite chuck
- Gases (HCl, N_2, H_2, Cl_2)

- Hot zone*
- Crucible
- Ar

- Diamond wire

- Ag paste*
- Screens
- Chemicals (wet & gases)
- Gases
- Quartzware*

- Glass+
- Encapsulant
- J-box adhesive and potting material
- Frames, Al and steel
- Frame adhesive
- Junction box, ribbons, Cu wires, etc.

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A great example

Kalyon PV Factory, Present Day: Fully integrated GW factory Ankara Türkiye

Humans are able positively shaping the world

Kalyon PV 1.3GW solar power plant Karapinar Turkiye

Conclusion

- No need for more module capacity; need to achieve **better utilization** for existing module capacity; some module assembly operations likely to close down
- Despite policy uncertainty, **now is the time to invest in ingot/wafer and cell**
- **Invest in your workforce:** training training, education, and retention of your skilled workforce for the expected largest employment sector within electric power generation category
- FEOC language might finally give non-PRC equipment vendors a chance for a more **leveled playing field**
- Need to time ingot/wafer capacity to **equipment vendor capacity** and be open for phased quotas for PRC equipment (incl. crucibles and diamond wires)
- Need to **lobby for public funding** sustaining RD&D
- While UPV is likely not impacted due to rising demand and advantages of PV+ESS, DG PV will need **public support**

Thank you

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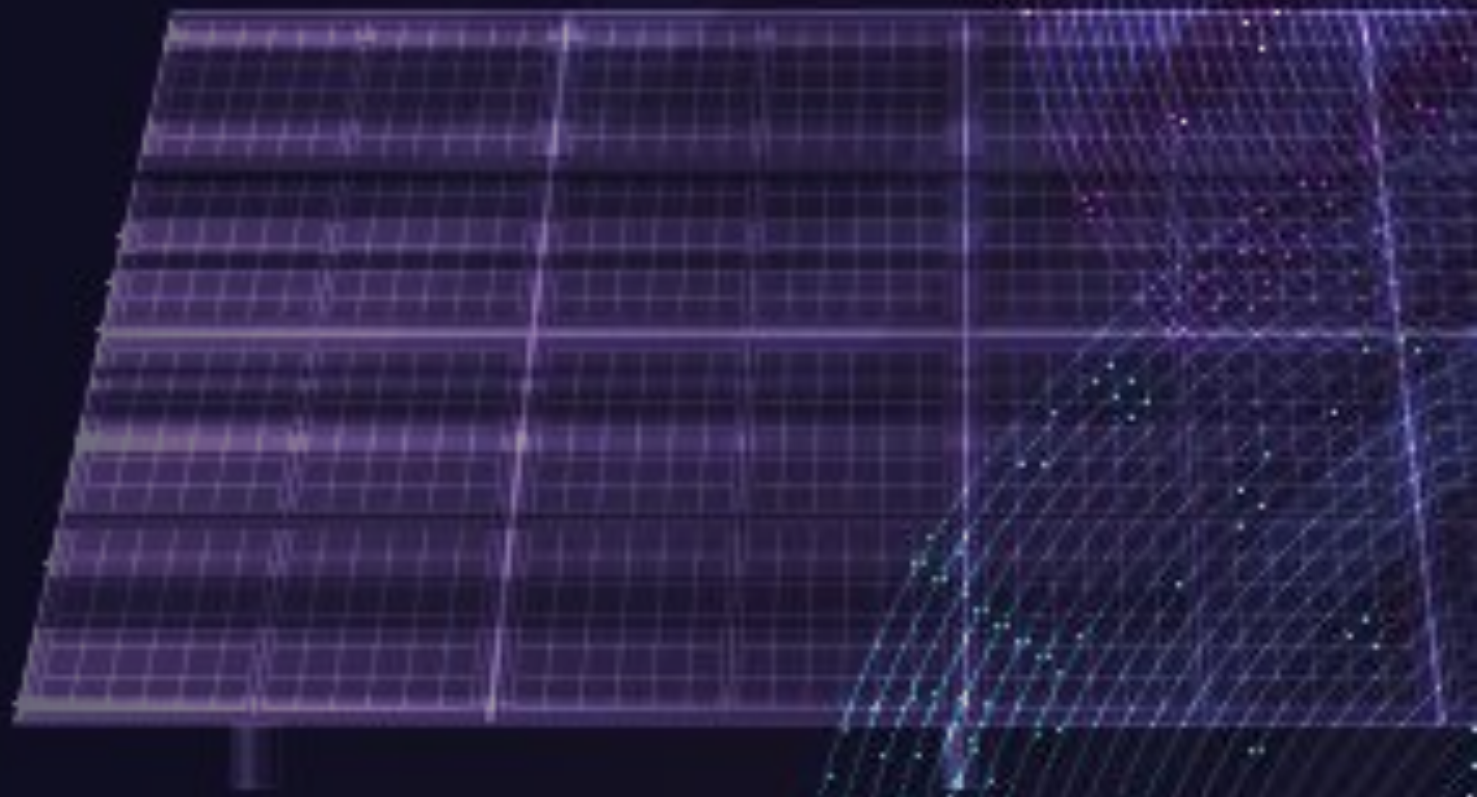
Confidential

Appendix

Exploring the PV supply chain landscape, this section highlights the details of local manufacturing, offering insights into current market trends and future opportunities for growth.



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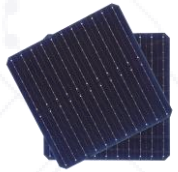
The PV ecosystem

Local integrated manufacturing along the value chain

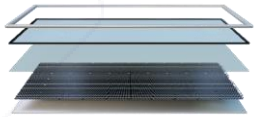
Mg-Si

Poly Silicon

Ingot & Wafer



Cell



Module

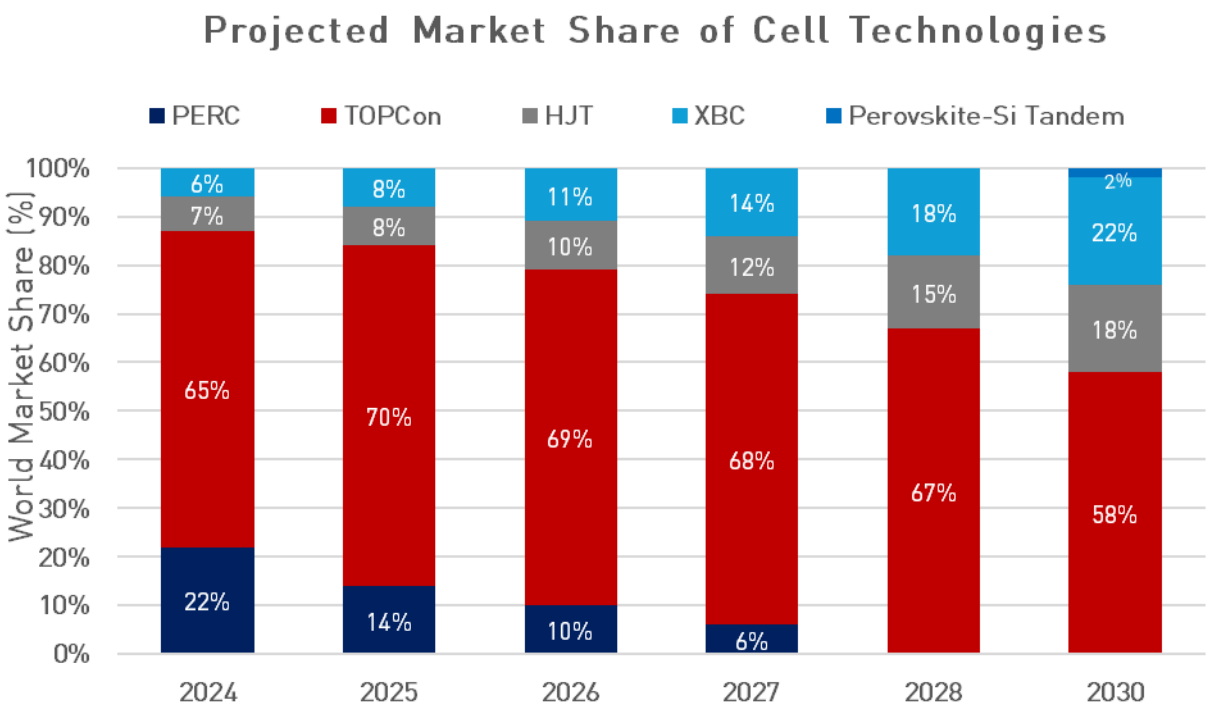
Equipment

Supply Chain / Materials

Technology / R & D / Institutes

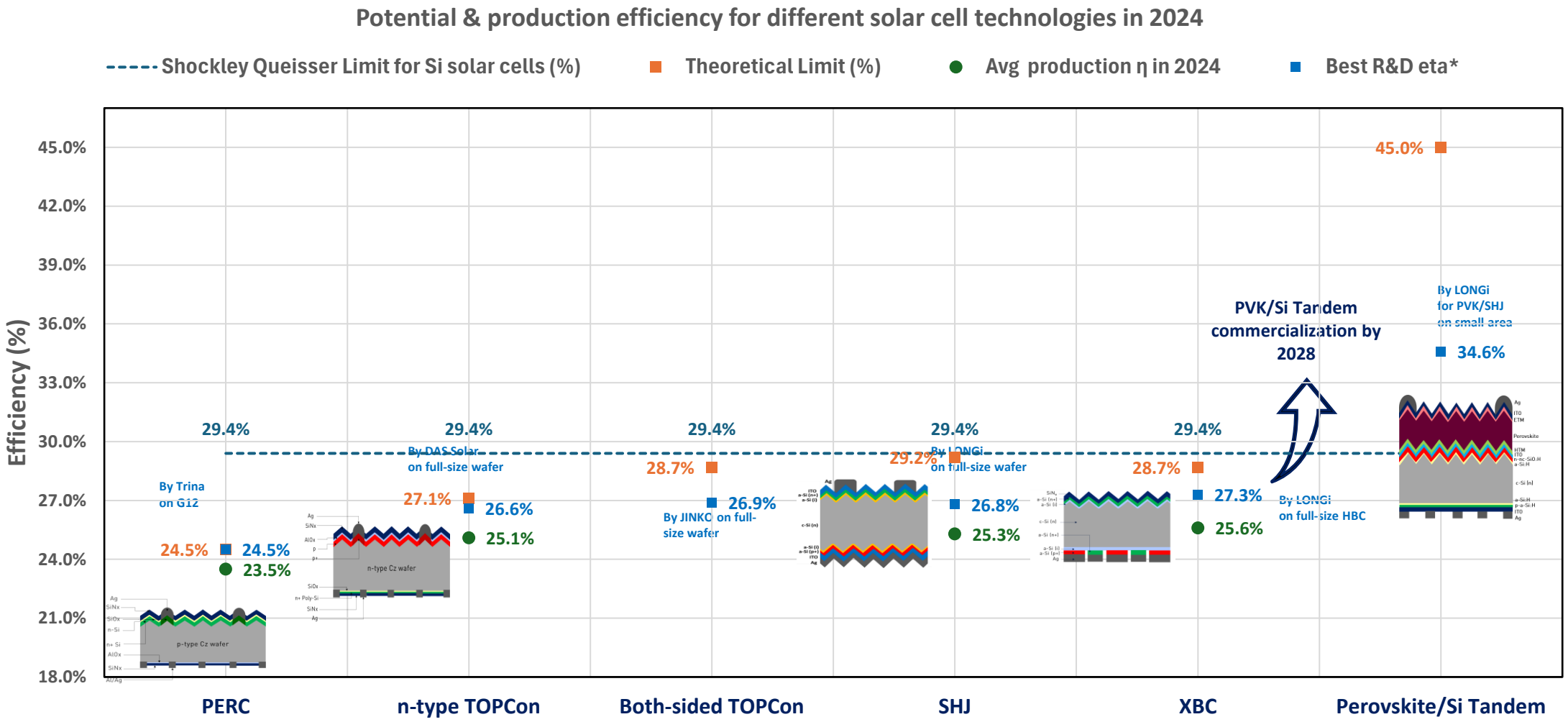
Training / Skills

Projected solar cell technology share till 2030



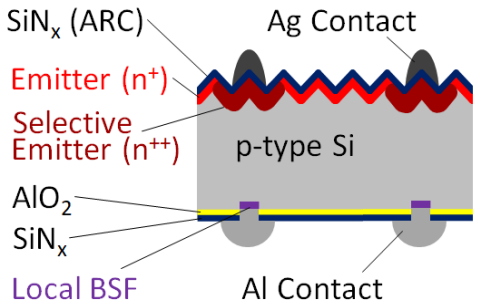
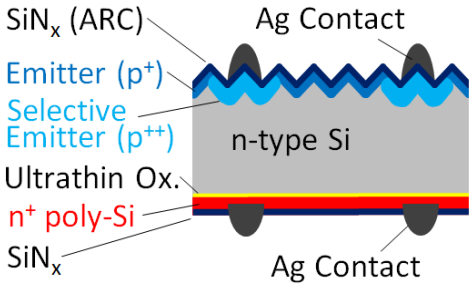
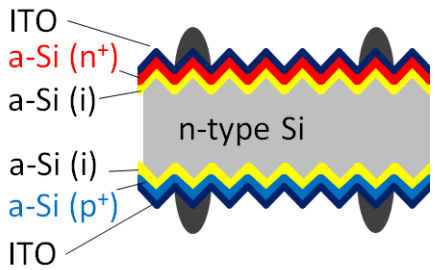
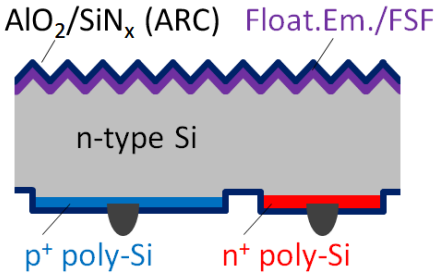
- BSF technology has completely phased off in 2024.
- PERC dominated till 2023 but it has only 22% market share in 2024 and expected to be phased out by 2027-2028.
- TOPCon is the new mainstream with more than 60% market share by end of 2024 and expected to hold major market share by 2030.
- SHJ technologies slowly gaining momentum and expected to have less than 20% market share by end of 2030 whereas XBC technology will have steady increase with more than 20% market share at the end of 2030.
- Perovskite/Si tandem may get 1-2% market share by 2030 if the technological problems are mitigated.

Solar cell efficiency limits & status



*- Efficiency can be higher by 0.6-0.7% abs

Overview of Current Solar Cell Concepts

Technology	PERC SE	TOPCon	HJT	TBC
Description	**P**assivated **E**mitter and **R**ear **C**ell with **S**elective **E**mitter	**T**unnel **O**xide **P**assivated **Con**tact Solar Cell with LECO	Silicon **H**etero **J**unction Solar Cell **T**echnology	**T**OPCon **B**ack **C**ontact Solar Cell with partial Cu metallization
Production Capacity	**250 GW**	**500-700+ GW**	**50 – 70+ GW**	**(10 - 20 GW, for XBC)**
Cell Eff. (Fab-Theoretical)	**23.2% → 24.5%***	**25.0% → 27.1%***	**25.2% → 28.5%***	**25.5% → 29.1%****
Cell Structure				

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