



RETHINKING INNOVATION

A first-principles view of how America can reinvent solar industrialization



ES Foundry Overview



- Established in Oct 2023
- Signed lease in May 2024
- Started construction in Sep 2024
- Grand opening in Jan 31st 2025
- Phase 1 Shipment started March 2025 (1GW)
- Phase 2 project started Nov 2025
- Phase 2 first cell (July 4th 2026)
- Phase 2 fully ramp up (total 3GW)
- ES Foundry is the largest US crystalline solar cell manufacture by shipment
- ESF officially joined MIT INM (initiative of New Manufacturing) in Sep 2026 as the first crystalline solar manufacture

What do we mean by “innovation”?



The industry usually starts with technology. First principles starts with the objective.



FIRST-PRINCIPLES QUESTION

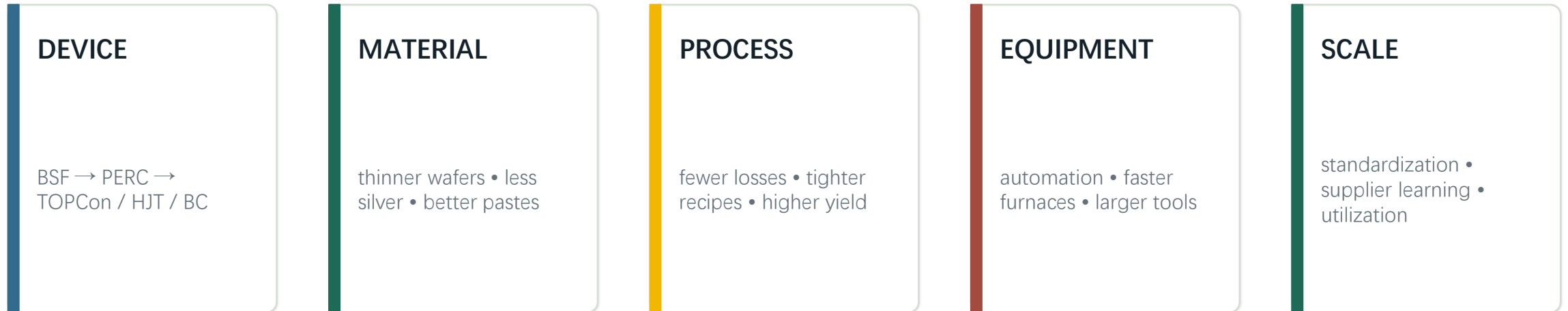
What outcome are we actually trying to maximize?

Not the most elegant process. Not the highest isolated tool metric. The most reliable, competitive, bankable watts.

Solar's cost revolution was never just invention



Learning came from technology, scale, process, equipment, yield and supply-chain repetition.



≈ 20%

historical PV module price reduction per doubling of cumulative volume

“Learning” is the result of specific actions and investments — not magic.

Sources of PV innovation



A U.S. factory should optimize the whole industrial system—not one technical variable.

GOOD WATTS OUT

TOTAL RESOURCES IN



**FACTORY
EFFICIENCY**

CAPEX

LABOR

ENERGY

MATERIAL

SPACE

TIME

More good watts. Less everything else.

Efficiency still matters—but it becomes one input into a broader manufacturing equation.

Constraints should produce a different optimization



A mature Asian PV cluster	The U.S. manufacturing environment
Dense supplier ecosystem	Thinner upstream supplier base
Fast equipment supply & service	Longer service and logistics loops
Extensive process-engineering talent	Need to rebuild process know-how
Large installed manufacturing base	Large existing industrial asset base
Highly optimized logistics	Strong automation and software capability
Decades of cumulative learning	Higher labor and construction cost

**American manufacturing system needs a design that fits its environment.
Copy Asia is not the way to go**

Remove before you improve



The highest-value process innovation may be the step, touch, queue or defect mechanism that disappears.

- 1 Why does this step exist?
- 2 Can we eliminate it?
- 3 Can we combine it?
- 4 Can we automate it?
- 5 **Only then: optimize it.**

OLD QUESTION

How do we make this process 5% cheaper & faster?

BETTER QUESTION

Why does the process need this step at all?

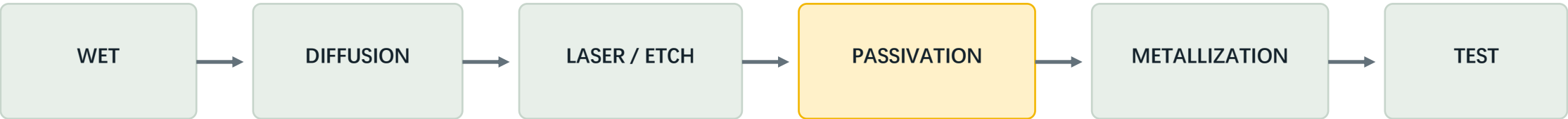
QUALITY QUESTION

Why was the defect created—not how fast can we inspect it?

Optimize the line, not the machine



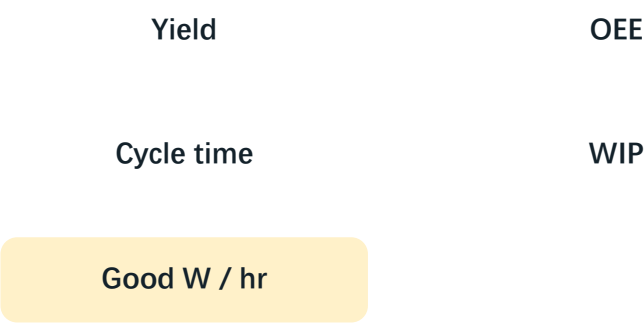
Local maximization can create global losses. The factory is a connected system.



A “faster” tool can still make the factory slower

if it increases WIP, creates mismatch, raises downtime, shifts defects downstream or requires more labor.

SYSTEM KPIs



Labor out of variability—not people out of value



Use automation, data and AI where humans add the least value. Move people toward engineering and improvement.

Repetitive	Predictable	Judgment
Material moves Loading / unloading Routine inspection	Recipe control SPC alerts Maintenance triggers	Root cause Process engineering Continuous improvement
Automate	Augment	Elevate

The goal is not fewer humans. It is fewer human-dependent failure modes.

A new KPI: Time-to-Watt

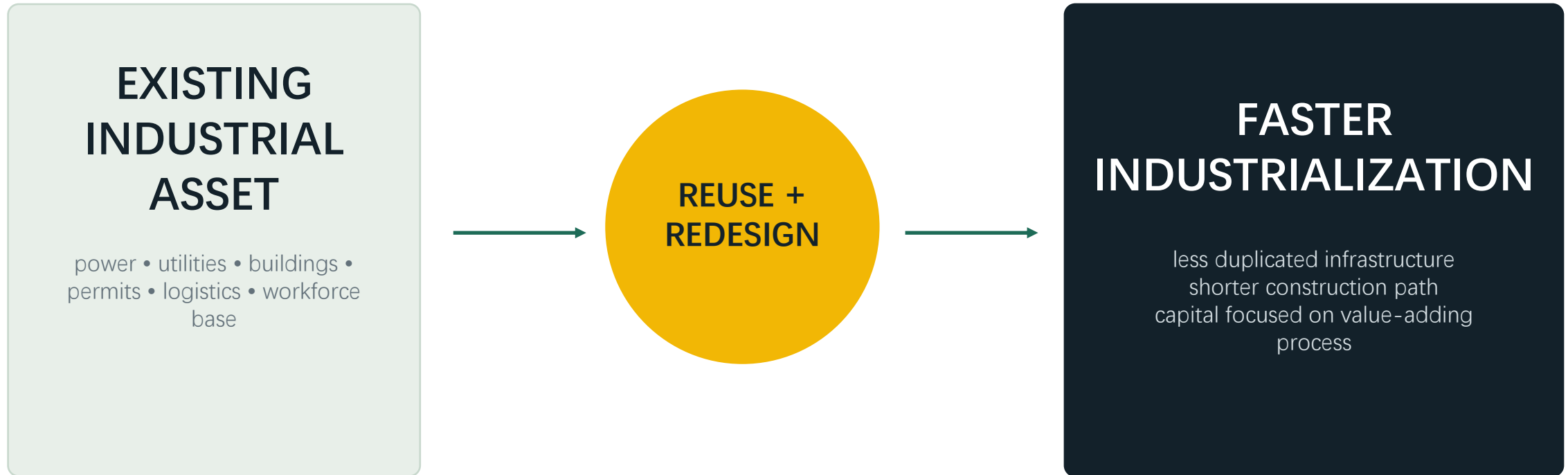


TIME-TO-WATT

How quickly does invested capital become stable, bankable, saleable output?

Technology risk × construction × commissioning × learning curve × yield stabilization

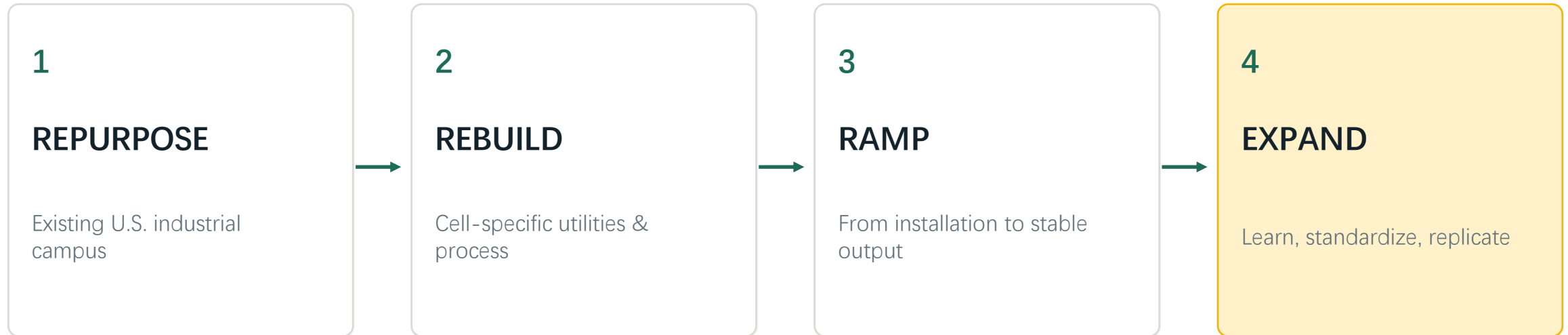
Brownfield can be an innovation strategy



ES Foundry: industrialization as the product



Our experience is not a universal blueprint. It is evidence that the manufacturing model itself can be redesigned.



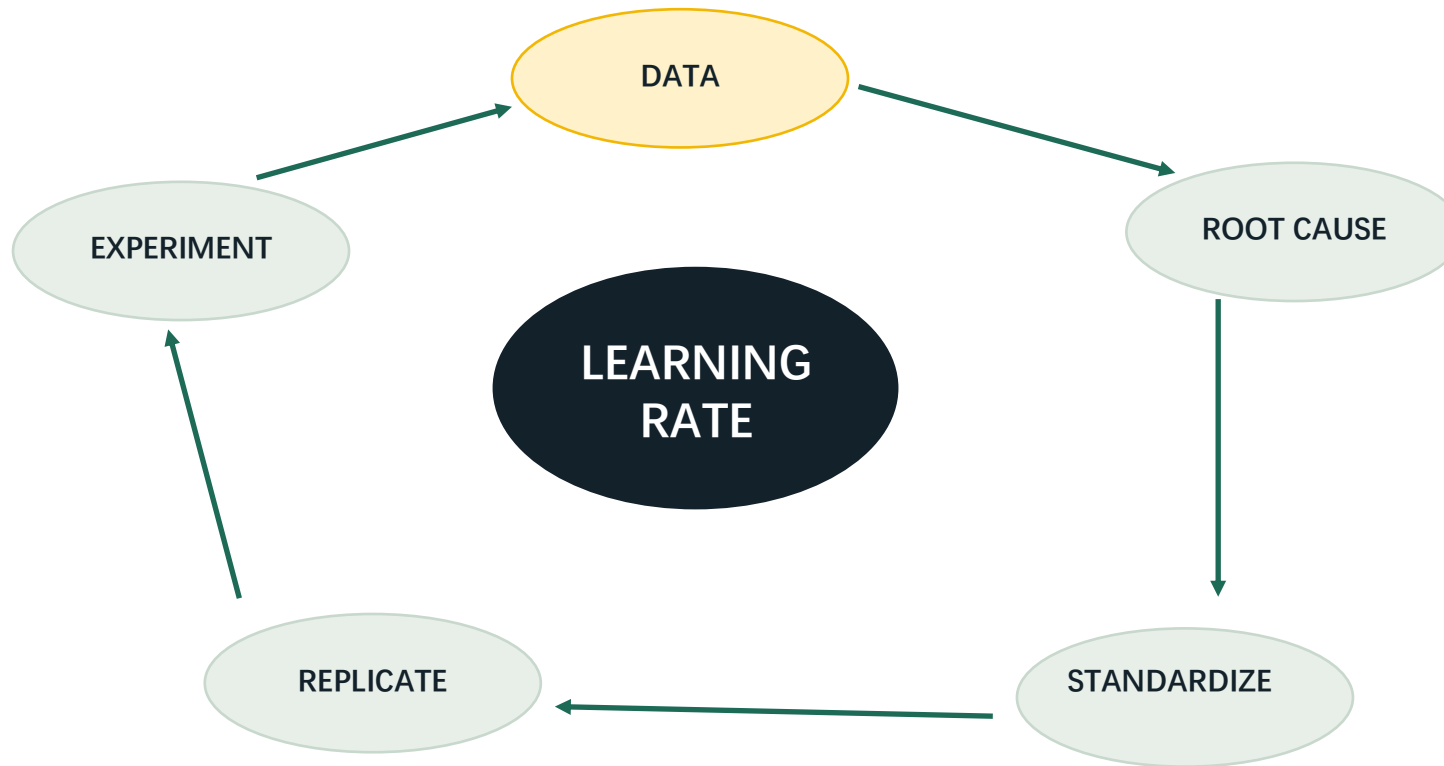
The lesson is not “copy ES Foundry.”

The lesson is: challenge every inherited assumption about how a U.S. cell factory must be built and operated.

The factory as a learning machine



The competitive advantage is not one recipe. It is the rate at which the organization learns.



Yield ↑ Downtime ↓ Cycle time ↓ Ramp speed ↑

Capacity is not the same as capability



Gigawatts measure today's output. Capability measures tomorrow's improvement.

CAPACITY

What can we produce today?

GW / year

CAPABILITY

How fast can we improve tomorrow?

learning / year

America needs both.

THE NEXT BREAKTHROUGH

MAY NOT COME FROM THE CELL.
IT MAY COME FROM HOW WE MAKE IT.

**Don't just innovate the cell.
Innovate the way we make it.**

Thank you