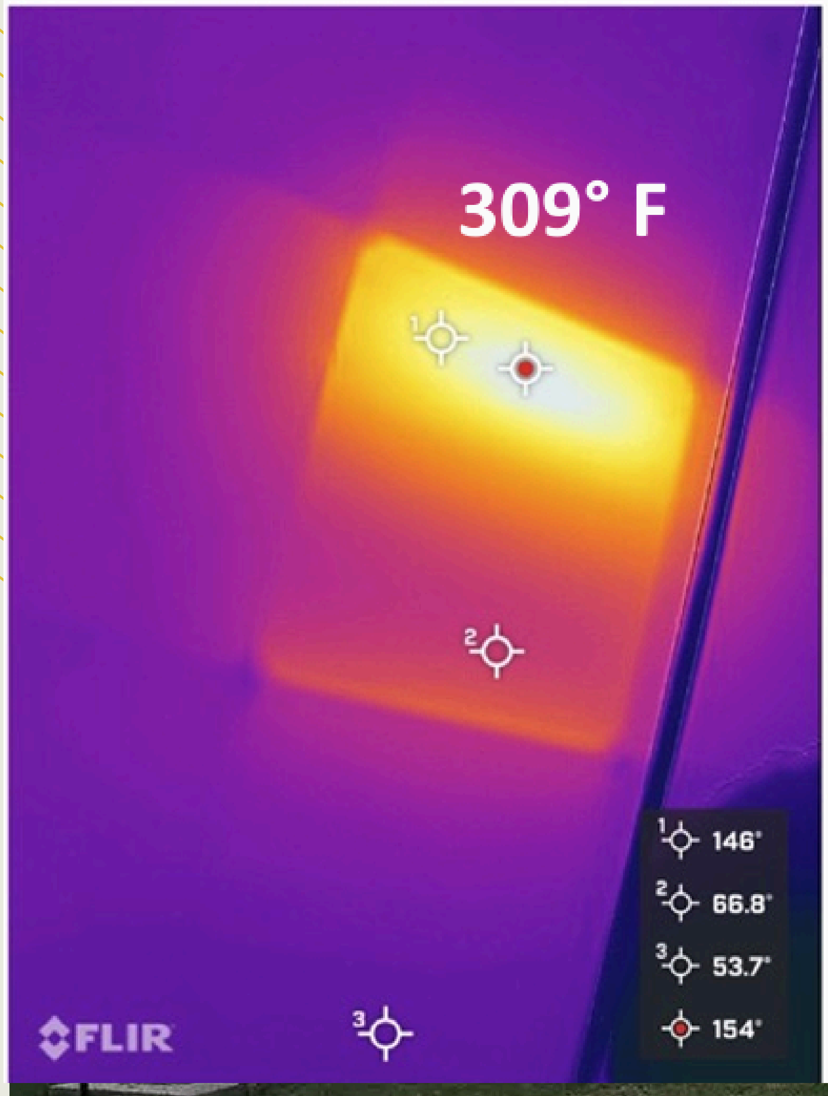
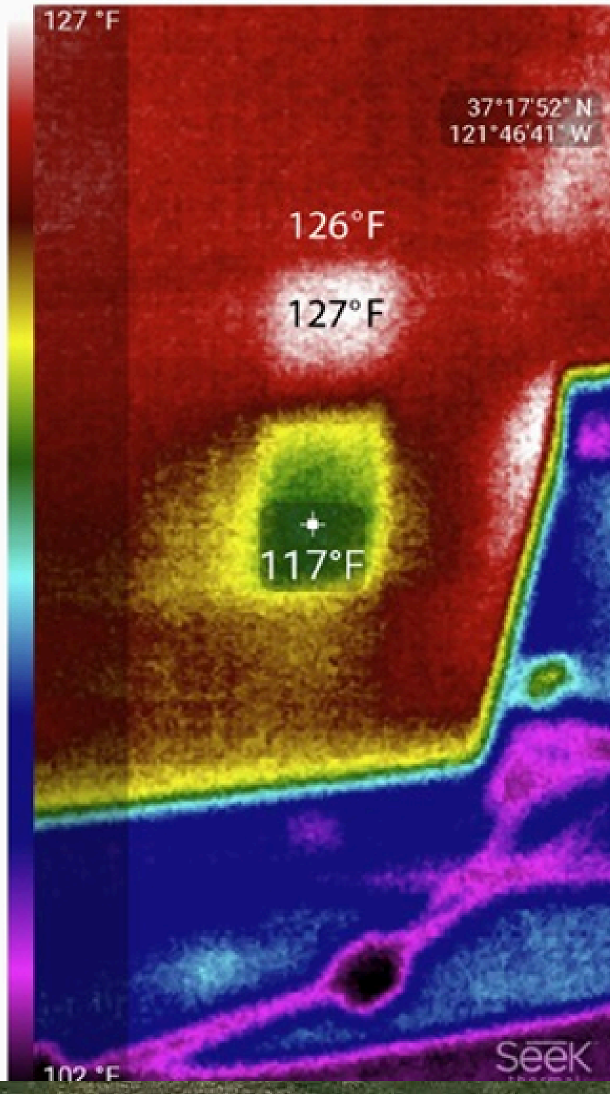
idealPV

The Airbag of The Solar Energy Industry

Harvey Mudd College

Felix Peng, Amy Li, Anika Sharma, Katie Cheng





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Solar system fires are on the rise

Historically underreported by the U.S. Fire Administration, Lawrence Shaw of Higher Powered, LLC has found that fires at solar installations rose 36% from 2017 to 2018. With residential installations representing the majority of fires, he believes mandated infrared imaging could be the key to bringing the number down.

Walmart sues Tesla for negligence after solar panels catch fire at 7 stores

FEATURED

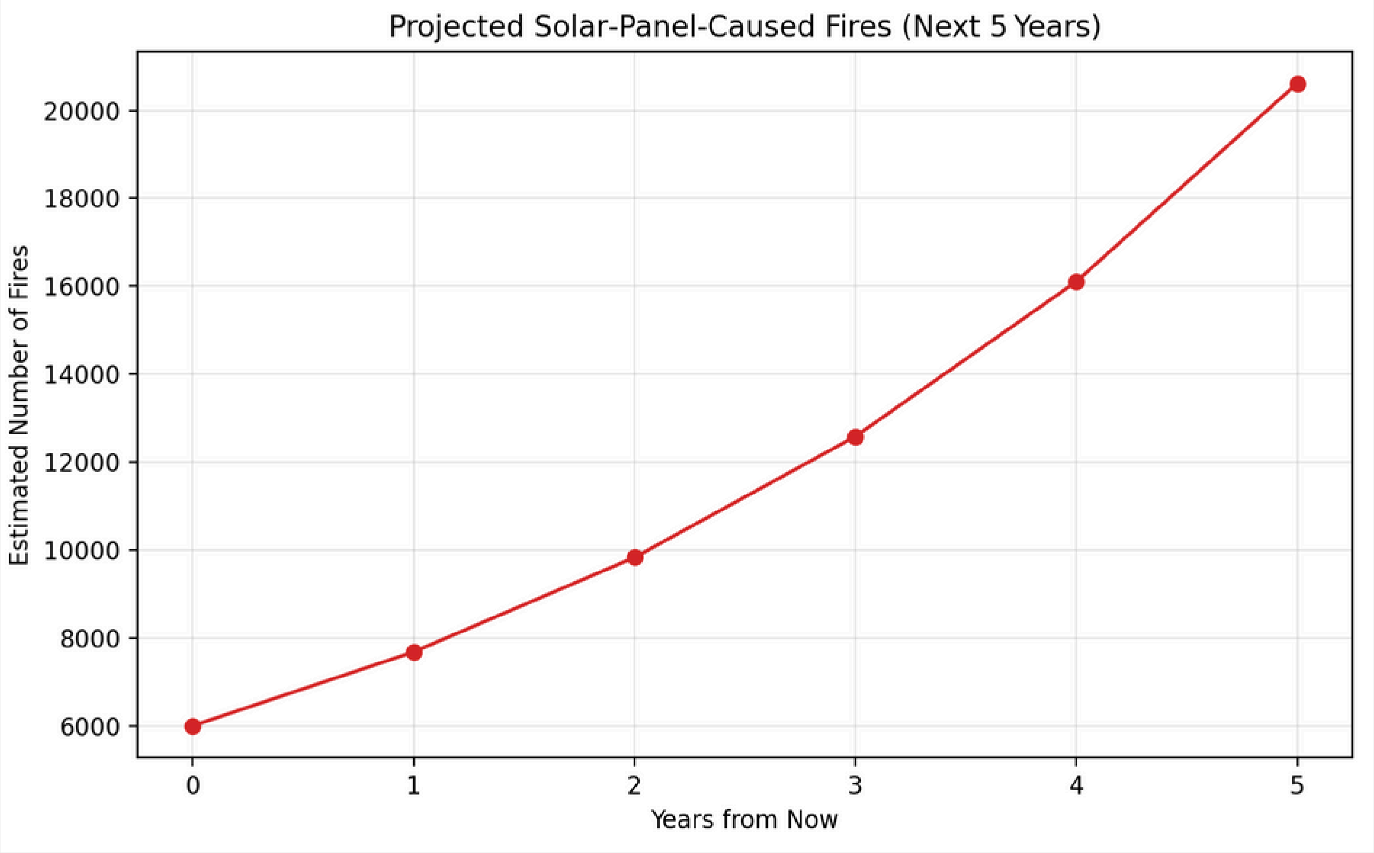
Fire chief: Solar panel fire brings concerns to forefront

By ETHAN SHOREY Valley Breeze Editor Jul 25, 2024 6

After a solar generator caused a house fire, American Family wants Amazon to pay

Courts have ruled both ways on whether the online retailing platform can be held liable for selling products that cause damage. The latest case involves a house fire in Minnesota.

QUANTIFYING THE PROBLEM



Rate of annual increase of solar panel adoption

36%

Risk of fires due to solar panels

0.006%

Number of solar panels in the US (residential and commercial)

110 mil

Number of fires due to solar panels in the US

6,000

Annual financial burden due to solar panel fires

$450 mil

This is just the tip of the iceberg...

There are –data missing– solar power fires per year

International data suggests that fires caused by rooftop solar power systems are rare; however, the United States doesn't centrally track this information – with the National Fire Data Center classifying them in the "other" category.

Solar Panels Endanger Firefighters

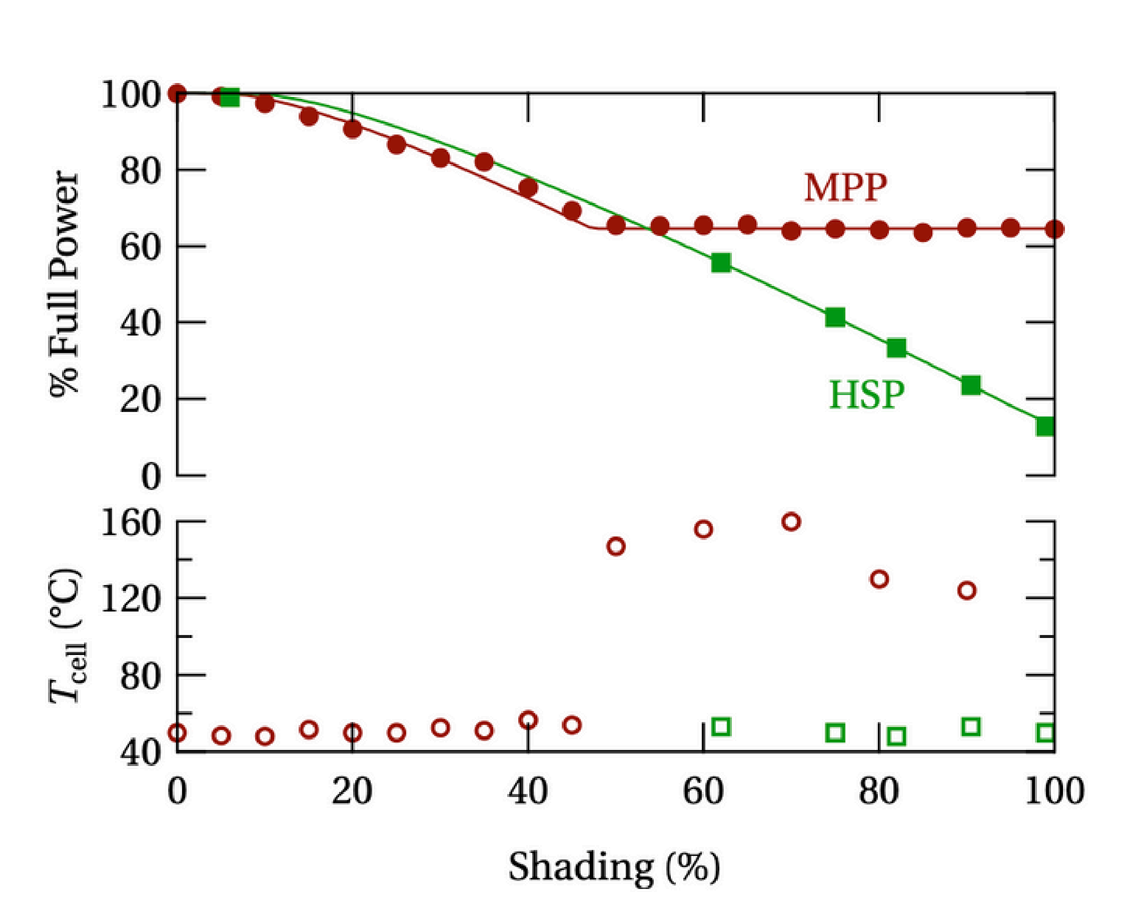
(Interview on 03/30 at LA Fire Dept Station 62)

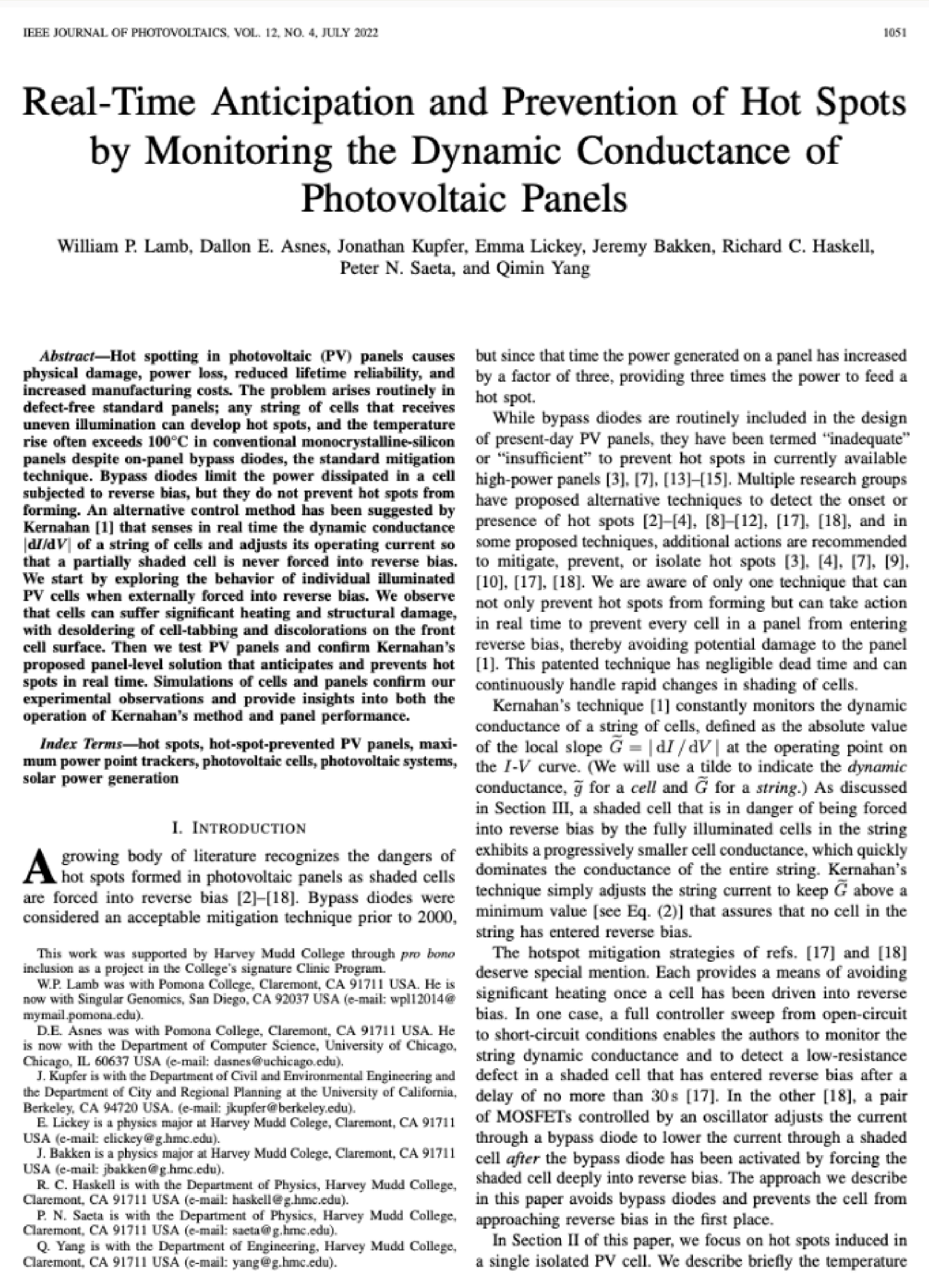
- Solar Panels can't **vertically ventilate**
- Firefighters avoid cutting through roofs with panels
- Case study:
  - 30,000 square meter building burned down in Delanco, NJ, simply because of panels on the roof

Solar panels spark deadly fires, and prevent effective firefighting.

THE TECHNOLOGY: HSP PANELS

idealPV's Hot-Spot Prevention (HSP) panels use real-time dynamic conductance monitoring to prevent reverse bias and hotspots.

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Real-Time Anticipation and Prevention of Hot Spots by Monitoring the Dynamic Conductance of Photovoltaic Panels

William P. Lamb, Dallon E. Asnes, Jonathan Kupfer, Emma Lickey, Jeremy Bakken, Richard C. Haskell, Peter N. Saeta, and Qimin Yang

***Abstract*—Hot spotting in photovoltaic (PV) panels causes physical damage, power loss, reduced lifetime reliability, and increased manufacturing costs. The problem arises routinely in defect-free standard panels; any string of cells that receives uneven illumination can develop hot spots, and the temperature rise often exceeds 100°C in conventional monocrystalline-silicon panels despite on-panel bypass diodes, the standard mitigation technique. Bypass diodes limit the power dissipated in a cell subjected to reverse bias, but they do not prevent hot spots from forming. An alternative control method has been suggested by Kernahan [1] that senses in real time the dynamic conductance $|dI/dV|$ of a string of cells and adjusts its operating current so that a partially shaded cell is never forced into reverse bias. We start by exploring the behavior of individual illuminated PV cells when externally forced into reverse bias. We observe that cells can suffer significant heating and structural damage, with desoldering of cell-tabbing and discolorations on the front cell surface. Then we test PV panels and confirm Kernahan's proposed panel-level solution that anticipates and prevents hot spots in real time. Simulations of cells and panels confirm our experimental observations and provide insights into both the operation of Kernahan's method and panel performance.**

***Index Terms*—hot spots, hot-spot-prevented PV panels, maximum power point trackers, photovoltaic cells, photovoltaic systems, solar power generation**

I. Introduction

A growing body of literature recognizes the dangers of hot spots formed in photovoltaic panels as shaded cells are forced into reverse bias [2]–[18]. Bypass diodes were considered an acceptable mitigation technique prior to 2000, but since that time the power generated on a panel has increased by a factor of three, providing three times the power to feed a hot spot.

While bypass diodes are routinely included in the design of present-day PV panels, they have been termed "inadequate" or "insufficient" to prevent hot spots in currently available high-power panels [3], [7], [13]–[15]. Multiple research groups have proposed alternative techniques to detect the onset or presence of hot spots [2]–[4], [8]–[12], [17], [18], and in some proposed techniques, additional actions are recommended to mitigate, prevent, or isolate hot spots [3], [4], [7], [9], [10], [17], [18]. We are aware of only one technique that can not only prevent hot spots from forming but can take action in real time to prevent every cell in a panel from entering reverse bias, thereby avoiding potential damage to the panel [1]. This patented technique has negligible dead time and can continuously handle rapid changes in shading of cells.

Kernahan's technique [1] constantly monitors the dynamic conductance of a string of cells, defined as the absolute value of the local slope $\tilde{G} = |\mathrm{d}I / \mathrm{d}V|$ at the operating point on the I-V curve. (We will use a tilde to indicate the *dynamic* conductance, $\tilde{g}$ for a *cell* and $\tilde{G}$ for a *string*.) As discussed in Section III, a shaded cell that is in danger of being forced into reverse bias by the fully illuminated cells in the string exhibits a progressively smaller cell conductance, which quickly dominates the conductance of the entire string. Kernahan's technique simply adjusts the string current to keep $\tilde{G}$ above a minimum value [see Eq. (2)] that assures that no cell in the string has entered reverse bias.

The hotspot mitigation strategies of refs. [17] and [18] deserve special mention. Each provides a means of avoiding significant heating once a cell has been driven into reverse bias. In one case, a full controller sweep from open-circuit to short-circuit conditions enables the authors to monitor the string dynamic conductance and to detect a low-resistance defect in a shaded cell that has entered reverse bias after a delay of no more than 30 s [17]. In the other [18], a pair of MOSFETs controlled by an oscillator adjusts the current through a bypass diode to lower the current through a shaded cell *after* the bypass diode has been activated by forcing the shaded cell deeply into reverse bias. The approach we describe in this paper avoids bypass diodes and prevents the cell from approaching reverse bias in the first place.

In Section II of this paper, we focus on hot spots induced in a single isolated PV cell. We describe briefly the temperature

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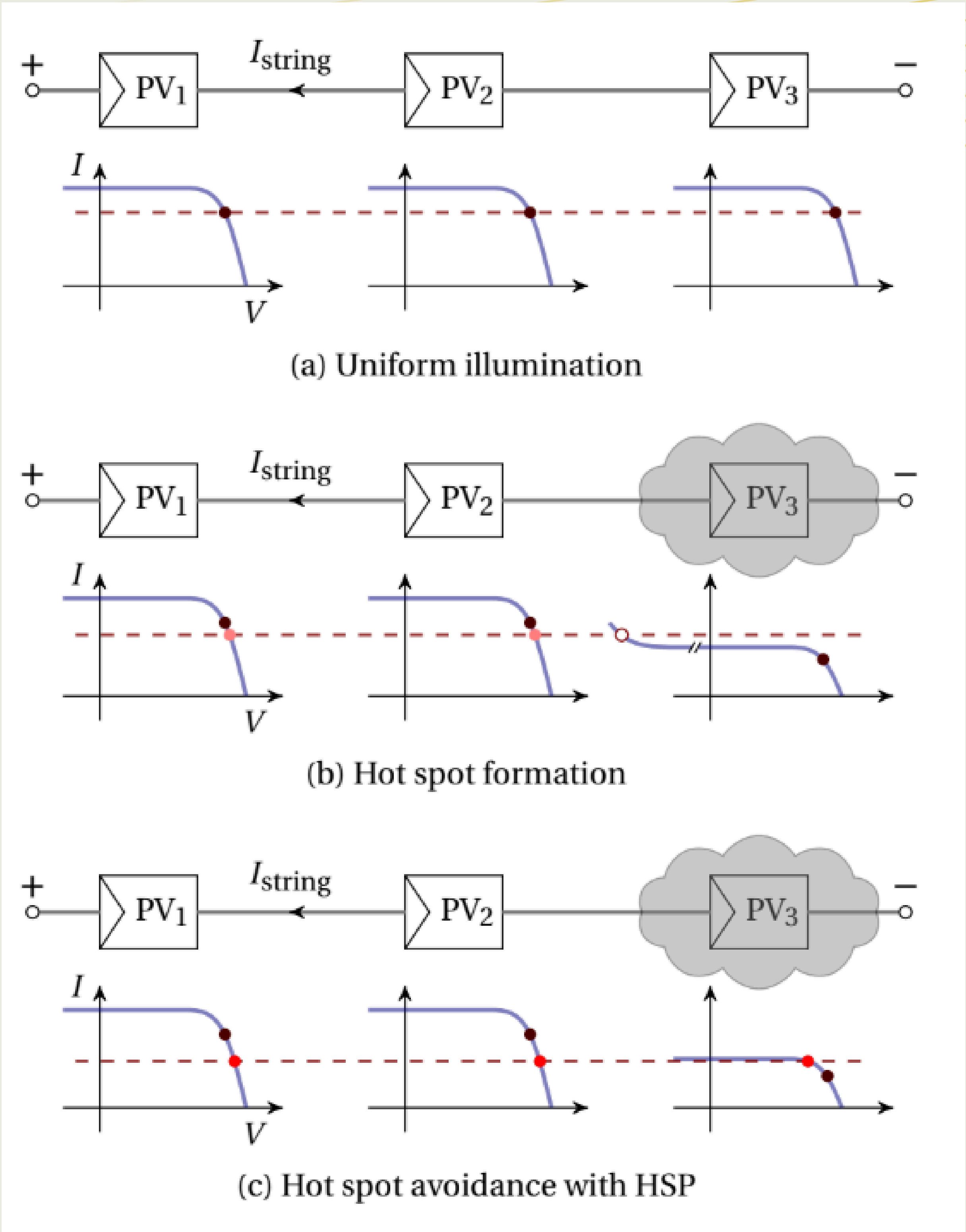


With this technology…

- hotspots simply don’t occur
- firefighting on homes is safer

IDEALPV: UNIQUE VALUE PROPOSITION

100%
protection against hot spots

3-4% less
wire power losses

80% lower
degradation rate

4-6% more
raw potential power

20% more
AC kWh than conventional

71% more
power produced in 1 panel’s life

COMPARING CURRENT SOLUTIONS TO HOTSPOTS

Features:	idealPV Panels	Anti-shading MPPTs	Bypass Diodes MPPTs	Air Flow Cooling Systems
Guaranteed Hotspot Prevention	Yes	No	No	No
Performance under 25% shading	90%	67%	85%	43%
Lifespan of 1 panel	50 years	25-30 years	25-30 years	30 years
Power generated over 1 panel's life	~16,500kWh produced	~14,780kWh produced	~9,660kWh produced	~11,100kWh produced
Cost per panel	~$160	~$240	~$130	~$270

UNIQUE VALUE PROPOSITION

idealPV

Safety & Innovation

Focuses on safety through **prevention**, not just mitigation

Existing Foundations

Partnering with local community-based manufacturers

Potential for Expansion

Licensing and **upscaling** the technology

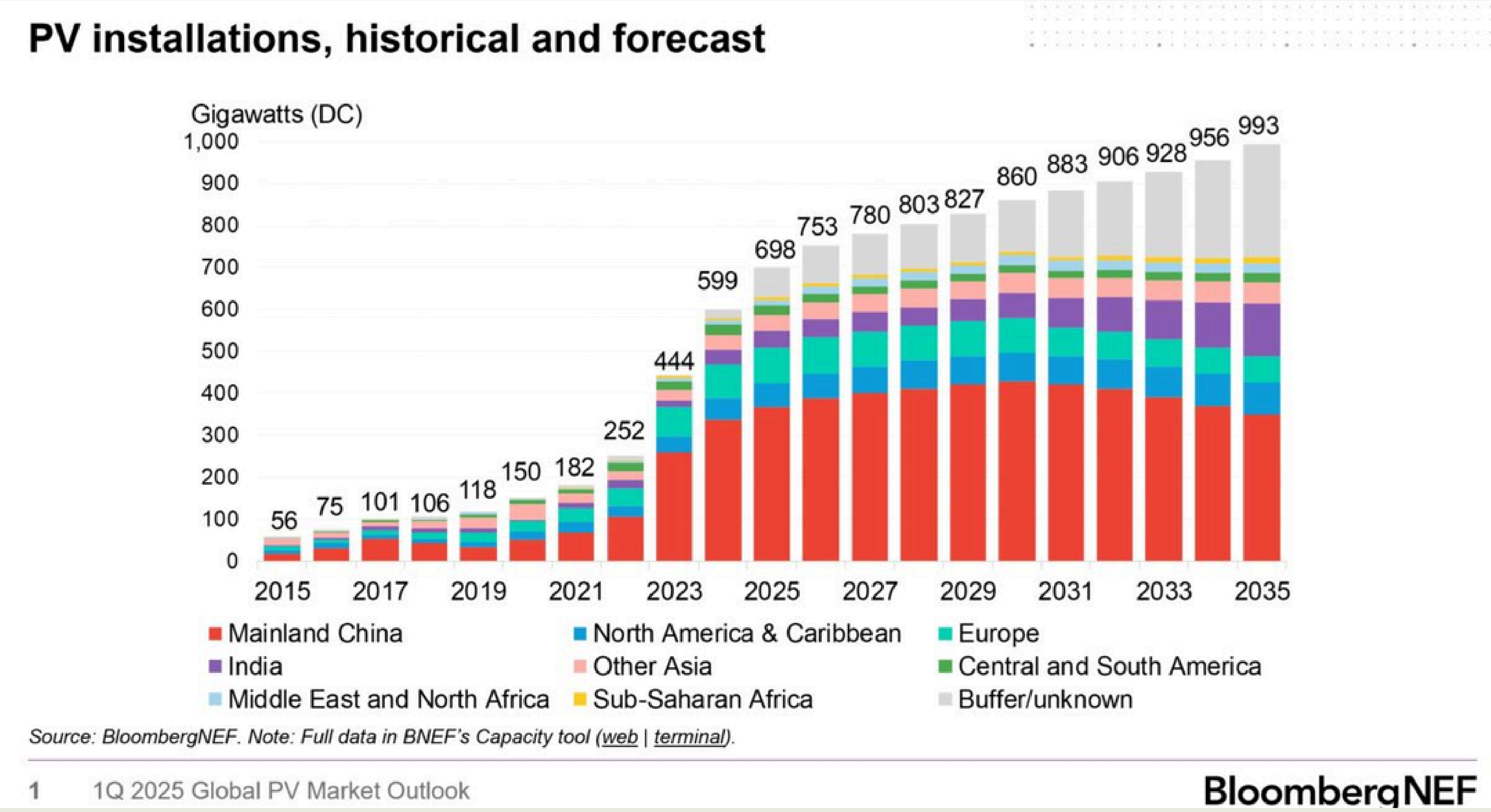
MARKET GROWTH

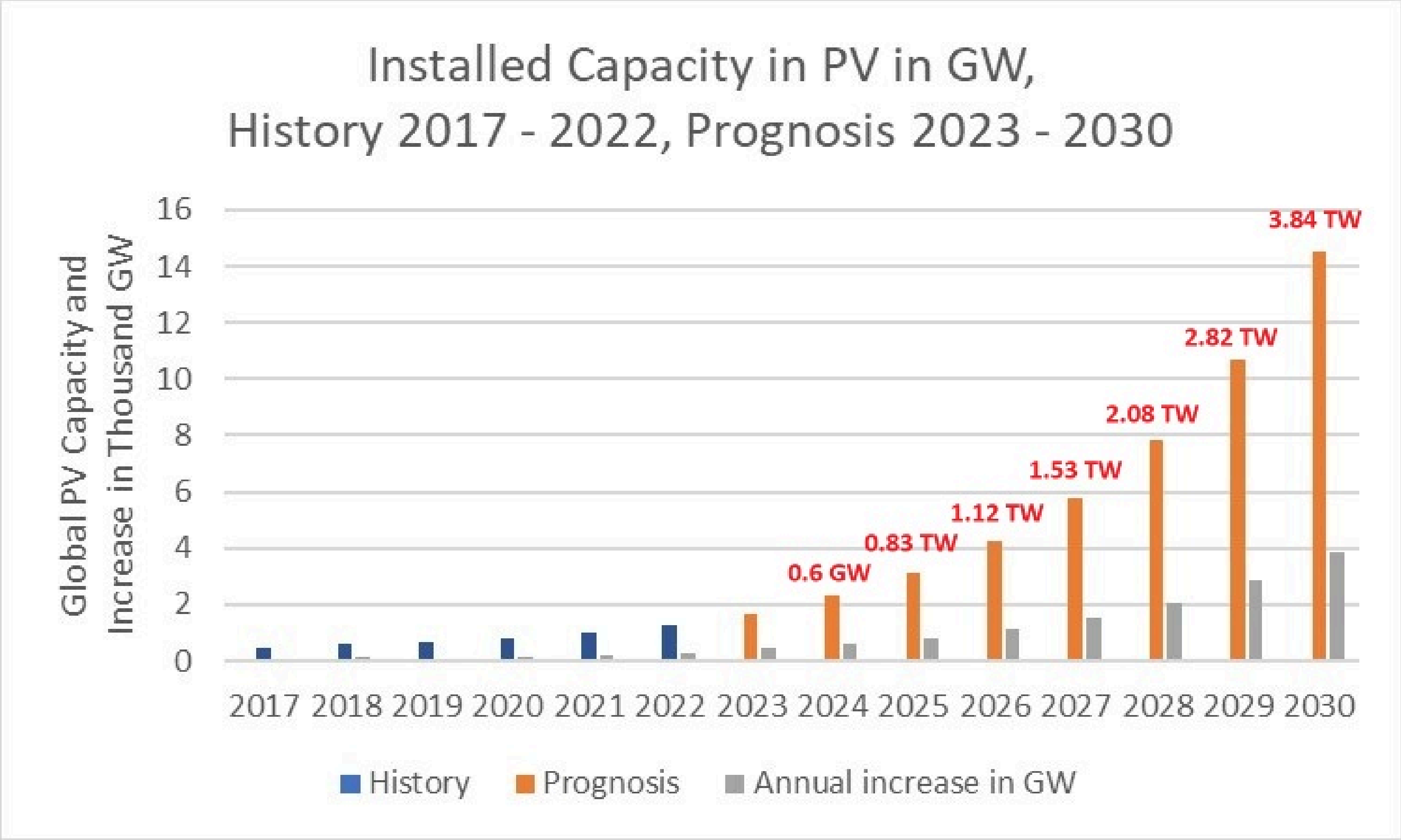
2024 - globally installed **599 GW** of solar, **35%** more than 2023.

2025 is projected to hit **698 GW** a **16%** increase

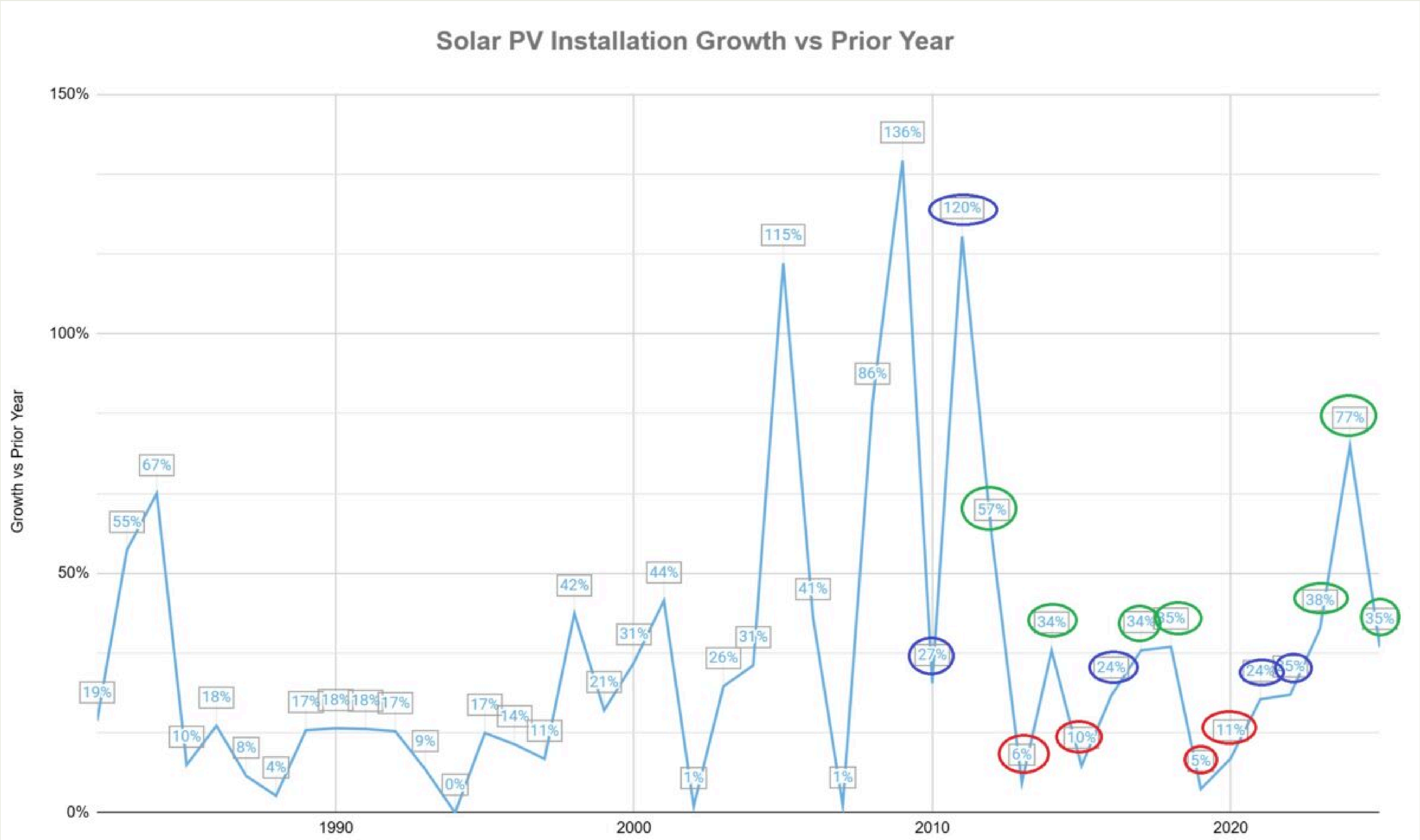
2026 - **1 Terawatt/year**

Average growth rate: **36% CAGR** (since 2010)





MARKET RELEVENCE FOR IDEALPV

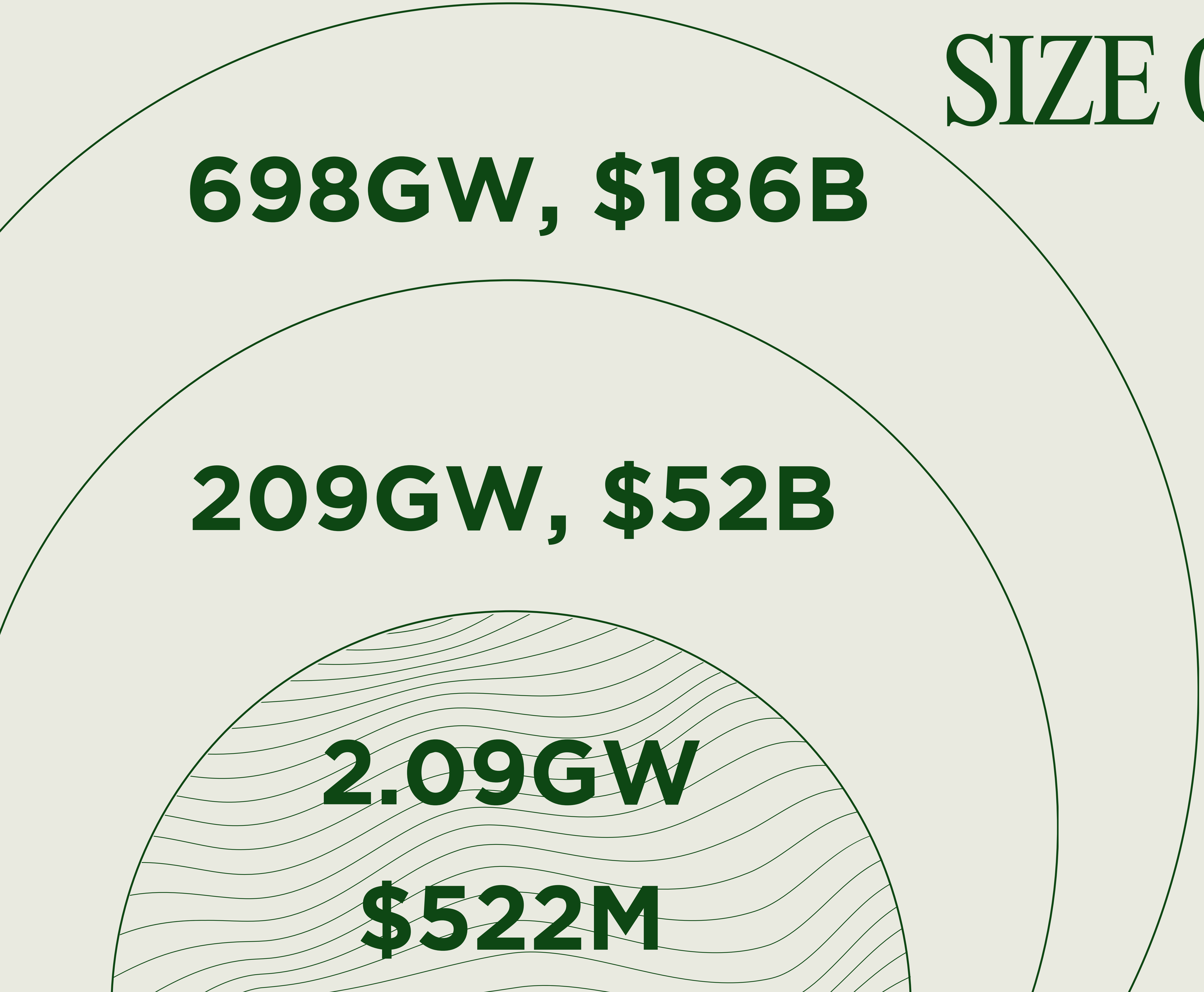


Global solar market exceeds **$200-300B** annually

Developers and manufacturers
- Tightening **fire safety** regulations
- Increase **panel longevity and reliability**

Solar generation = **5.6%** of the total U.S. electricity demand in 2023
Projected to serve **37%–42%** of electricity demand by 2035.

SIZE OF MARKET



TAM

Global solar PV market, 698 GW install potential in 2025, $186B annual panel market

SAM

$52B safety-driven solar panel market

SOM

2 GW **obtainable market**, $522M near-term opportunity

IMPLEMENTATION PLAN

6 months — Demonstrate

Work with **CHERP** to implement IdealPV in the **Claremont community**

1 year — Deal

Connect with **larger solar firms** to kickstart a collaboration

3 years — Develop

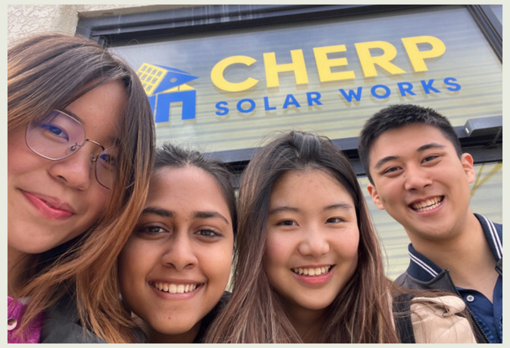
Refine the technology and implementation based on **feedback**

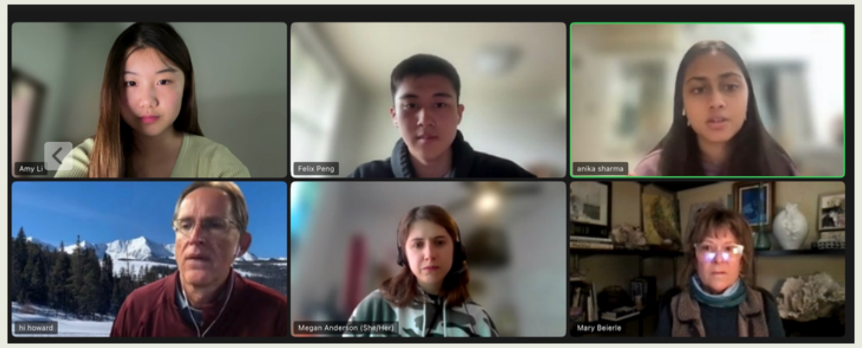
5 years — Distribute

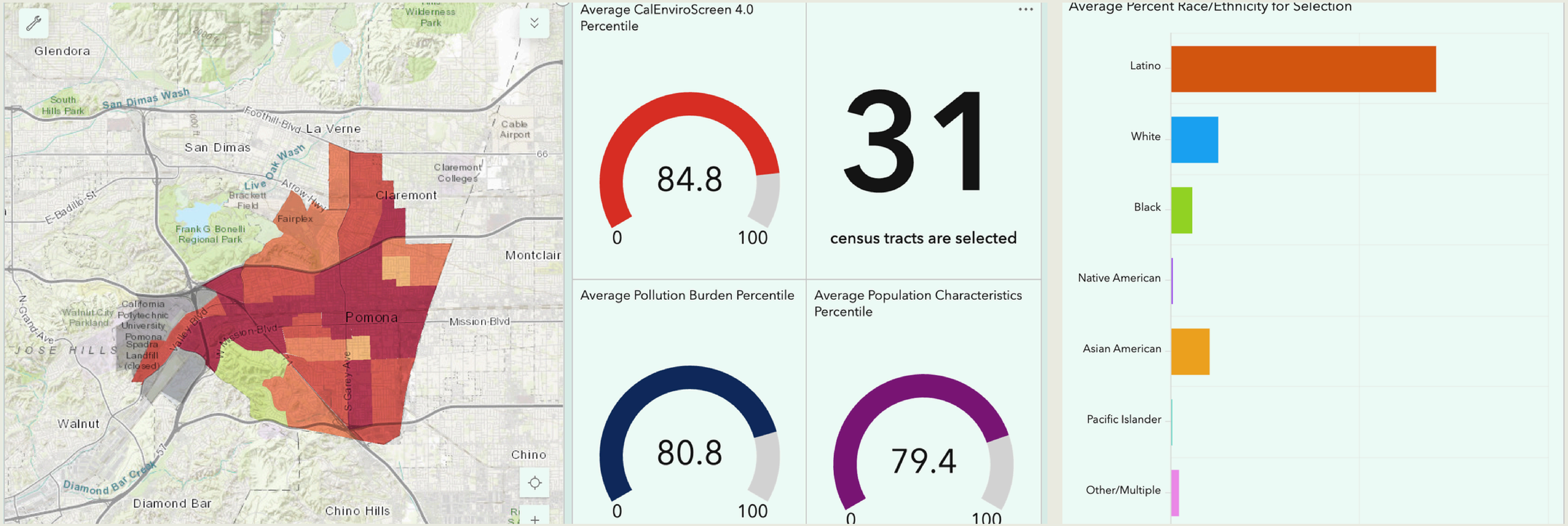
License the technology to larger solar firms to make **production widespread**

DEMONSTRATE

Work with **CHERP** to implement IdealPV in the **Claremont-Pomona community**







KPIs

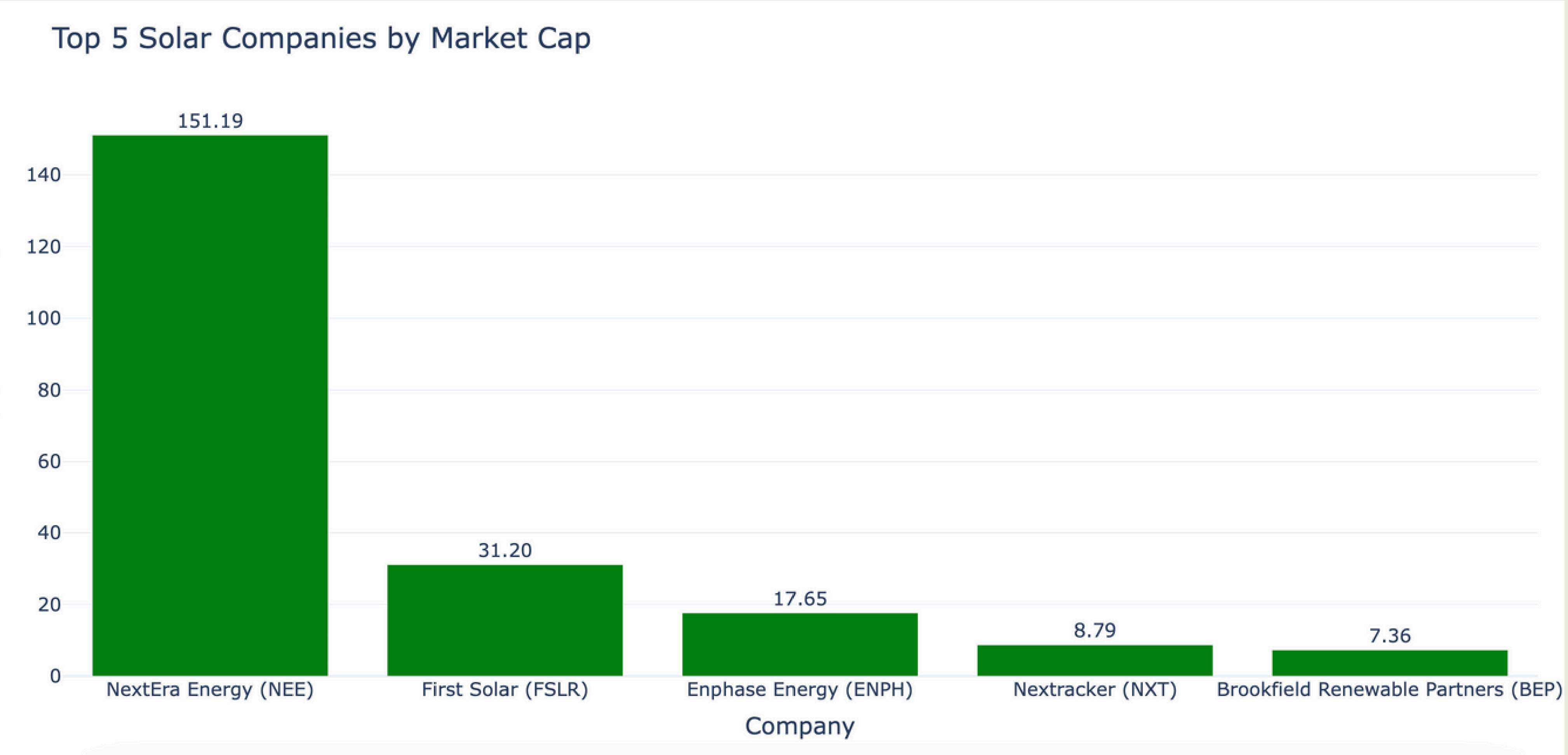
- **500** idealPV panels implemented across Claremont
- **760+** jobs created through CHERP

CHERP SOLAR WORKS

THE CLAREMONT COLLEGES

DEAL

Connecting with **larger solar firms** to kickstart a collaboration



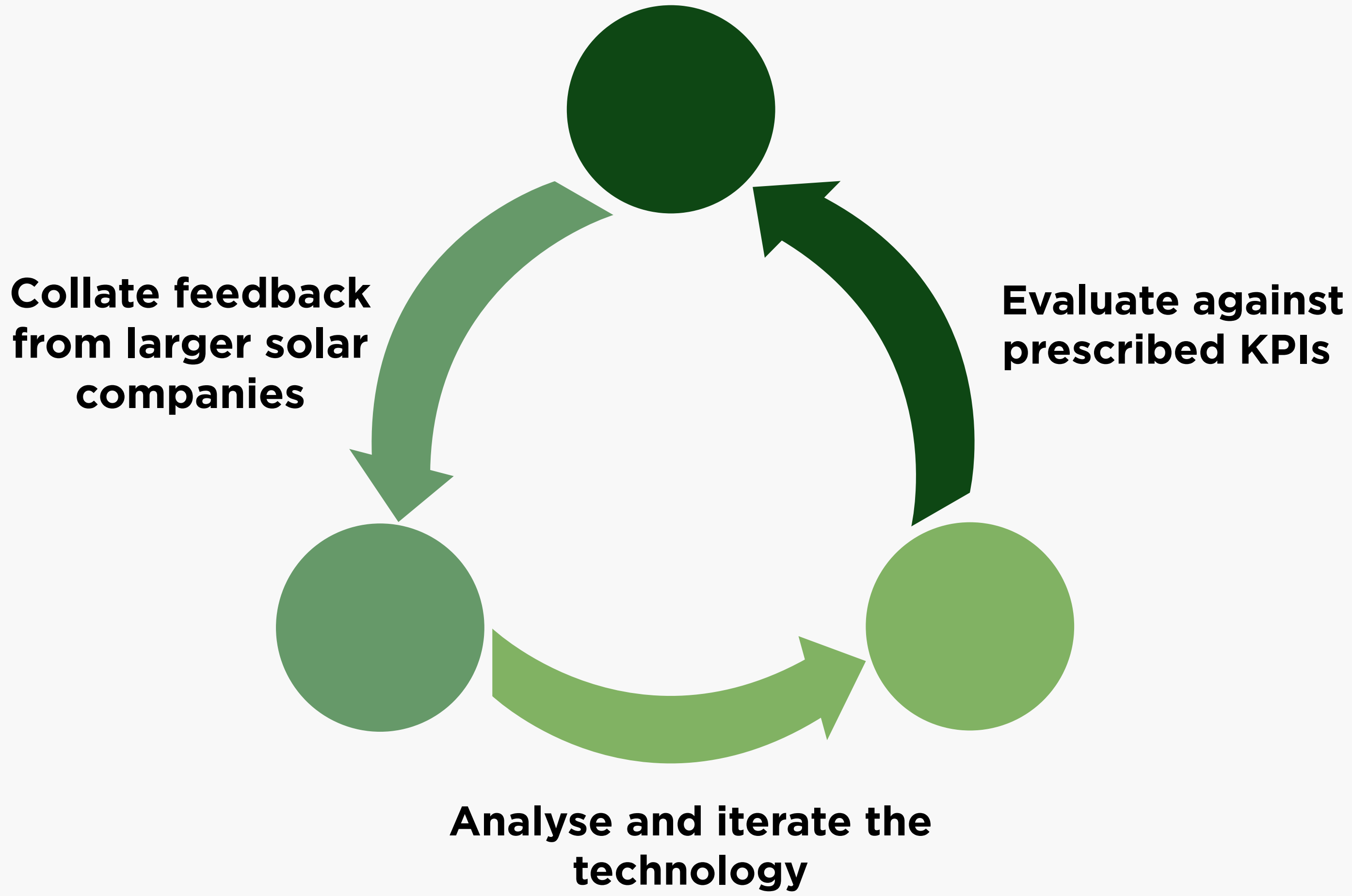
STAKEHOLDERS	WITHOUT IDEALPV	WITH IDEALPV
Our Direct Clients: Solar Factories	Lawsuits, short lifespan	Community outreach and reputation, lower costs
Local Communities	Fires and Safety Hazards	Lower risk of fire-associated harm

KPIs

- **5-10** large solar manufacturers connected with
- **Monthly reports** of monitoring and status of idealPV panels within the pilot community

DEVELOP

Refine the technology and implementation based on **feedback** from our customers: **Solar manufacturers**



- **Regulatory Confirmation**
- **Input from stakeholders**
- **Retrofitting R&D**

KPIs

- **2 lab** technology validations (NREL), **2** international **safety** certifications (IEC or UL)
- Claremont Pilot Program performance data and information (tech adoption rate)
- Licensing revenue greater than operating expenses

DISTRIBUTE

License the technology to larger solar firms to **make production widespread**

If certain **KPIs** are met: (e.g. 5% LCOE decrease), **cost per solar panel decreases proportionally**

$0.90/panel for first **$100,000** units

$50K base license upfront cost

1.5 million

saved per 100,000 panels produced

KPIs

- **Reduction in Levelized Cost Of Energy -** 5-10%
- **Technology Adoption Rate**

First Solar.

SUNPOWER®

COST STRUCTURE

idealPV pricing:

$160/panel

idealPV earns:

$0.90/panel

on every panel produced
(residual ongoing income)

Category	Estimated Cost
Product Development (one-time)	$120K
Certification, IP	$75K
Annual Operations	$300K/year

FINANCIAL PROJECTIONS

Metric	3 Months	6 Months	Year 1	Year 3
Panels Licensed	300,000	600,000	1,500,000	5,500,000
License Fee	$49,000	$48,000	$45,000	$31,670
Total Revenue (Upfront +$0.30/panel)	$279,000	$488,000	$1,115,000	$3,901,670
Operating Expenses	$70,000	$90,000	$120,000	$220,000
Net Profit	**$209,000**	**$398,000**	**$995,000**	**$3,681,679**

PROFITABILITY: HIGH MARGIN, SCALABLE

~94%
Operating Profit Margin by Year 3

$500K+ over 5 years
LTV per factory

~$5K
CAC per Factory

100+:1
LTV:CAC Ratio

Revenue scales with partners: Each factory adds predictable, recurring income + Economies of Scale

RISKS AND MITIGATION

Possible Challenges	Solutions
Solar manufacturers may hesitate to adopt idealPV	• Run **integration pilots** use that data to streamline integration on a large scale.
High upfront licensing costs, R&D expenses, and slow early adoption could create cash flow risks.	• Use a **phased licensing model**: lower initial fees, with revenue sharing from panel sales. • Crowdfund **community-based** implementations to reduce capital intensity.
New tech requires retraining solar panel installers and updating safety practices.	• Partner with **CHERP** to develop **certified training modules**. • Provide **installation guides + on-site support** for early partners.

tldr:

1. **The Tech: idealPV**
2. **The Solar Industry**
3. **Analyzing Economic Feasibility**
4. **Our Potential Impact**
5. **Success = Industry Standard**

Demonstrate Deploy Develop Distribute

IDEALPV WILL BE THE AIRBAG OF THE SOLAR INDUSTRY

CITATIONS

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