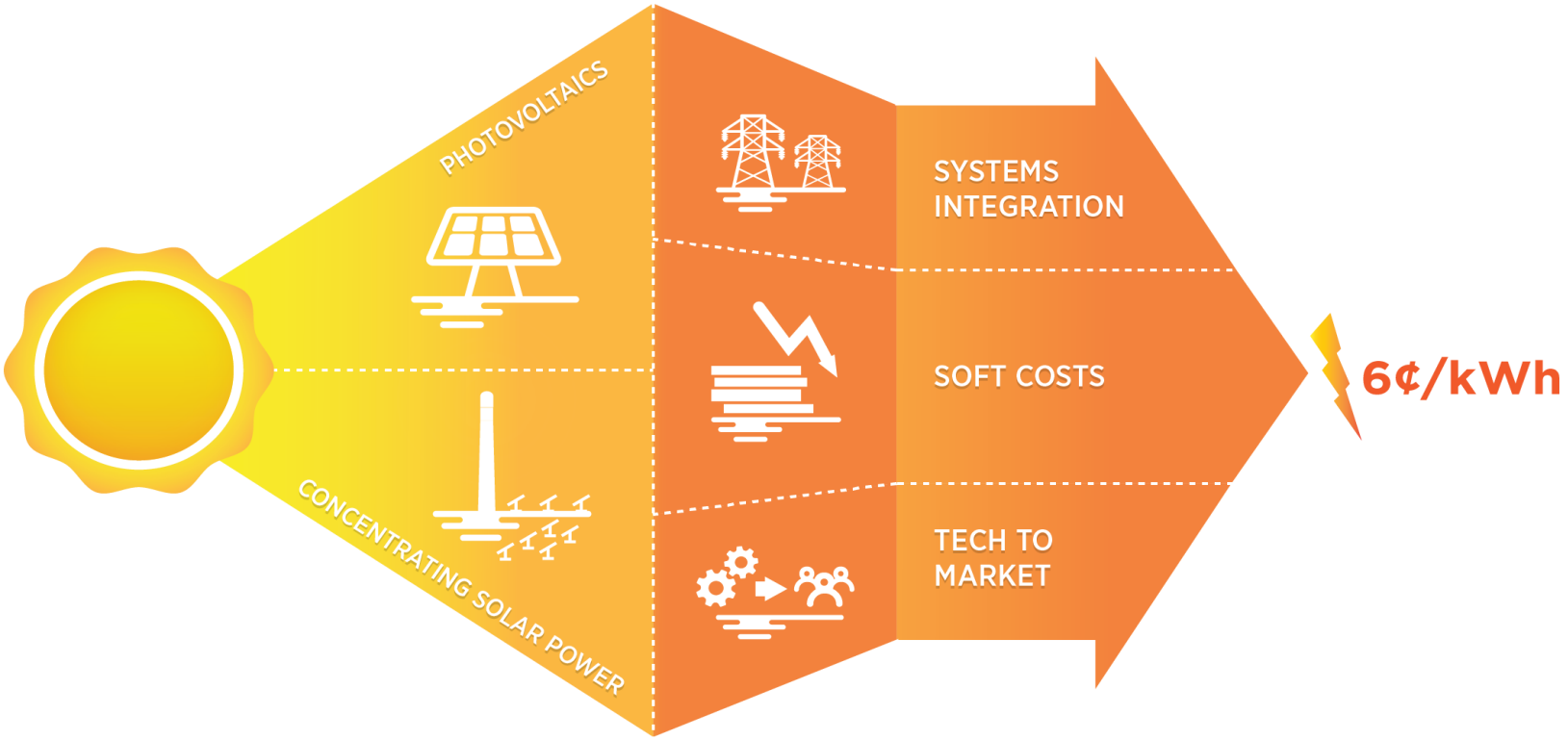
SunShot
U.S. Department of Energy

Developing Next Generation Power Electronics to Enable 100s GW of Solar

10/11/2016

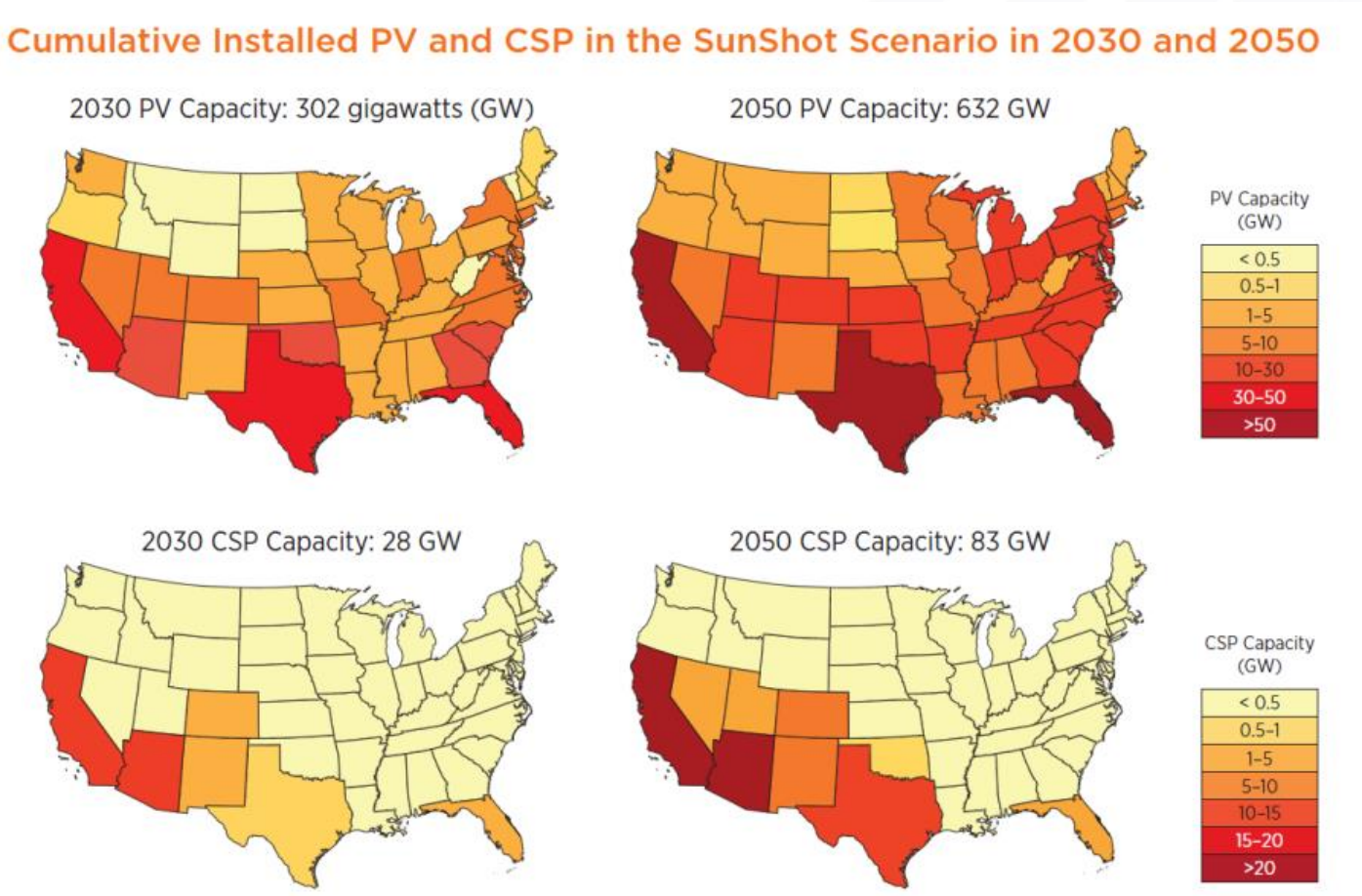
Guohui Yuan

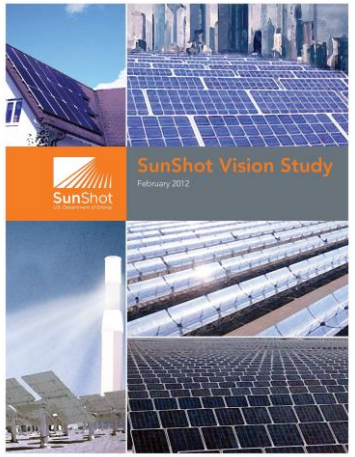
SunShot Initiative



SunShot Vision on Deployment

Solar can meet **14%** (300GW) by 2030 and **27%** (600 GW) by 2050 of U.S. electricity demand

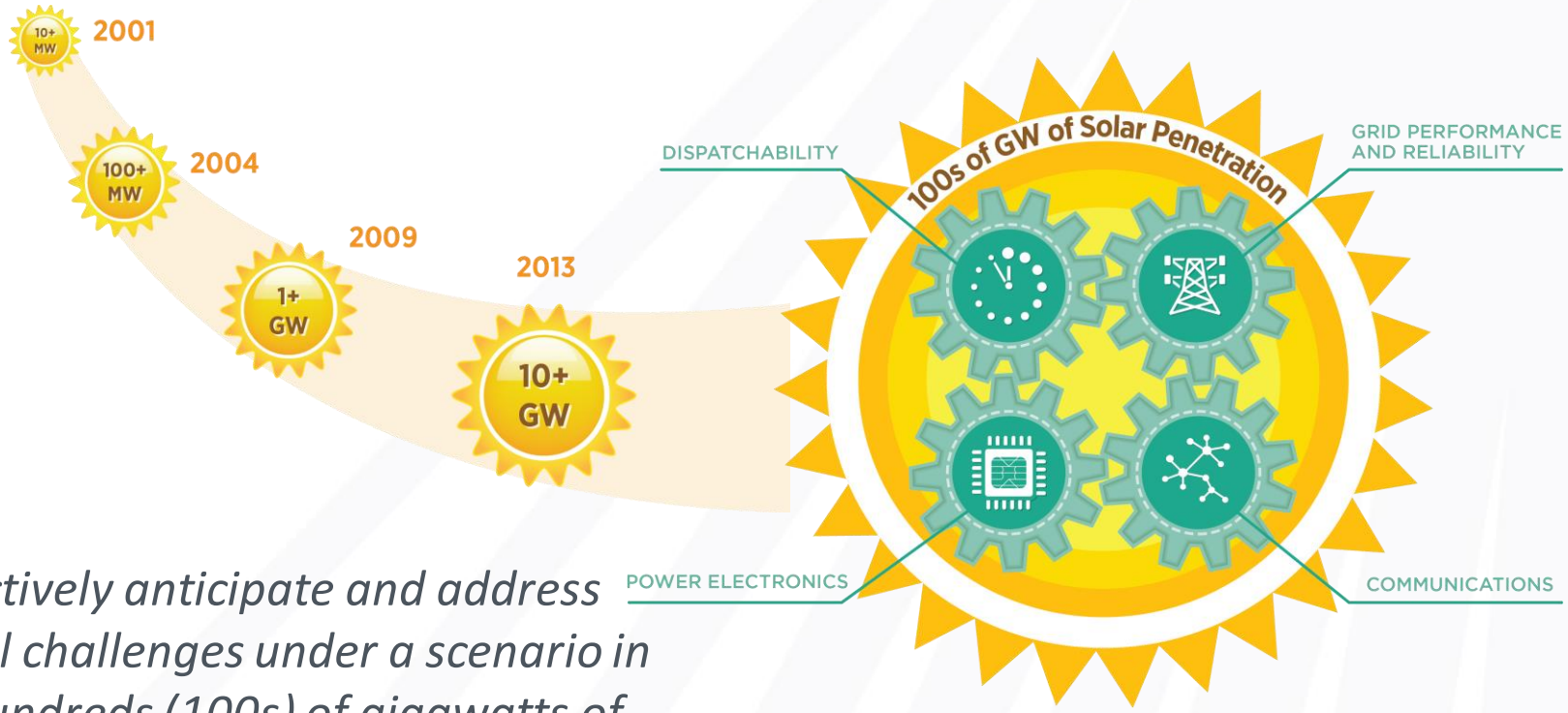




DOE SunShot Vision Study (2012)

SunShot U.S. Department of Energy

SunShot Systems Integration Vision



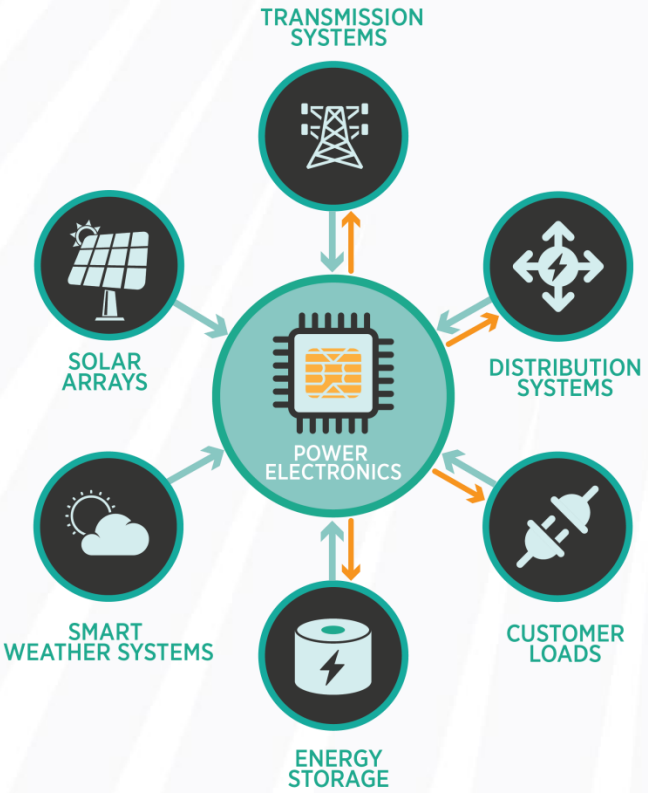
To proactively anticipate and address potential challenges under a scenario in which hundreds (100s) of gigawatts of solar energy are interconnected to the electricity grid, the SI sub-program has identified the challenges to be addressed in four broad, inter-related areas:

SunShot U.S. Department of Energy

Topic 3: Power Electronics and Control

Develop intelligent devices that maximize the power output from solar power plants and interface with the electric grid (or end use circuits), while ensuring overall system performance, safety, reliability, and controllability at minimum cost.

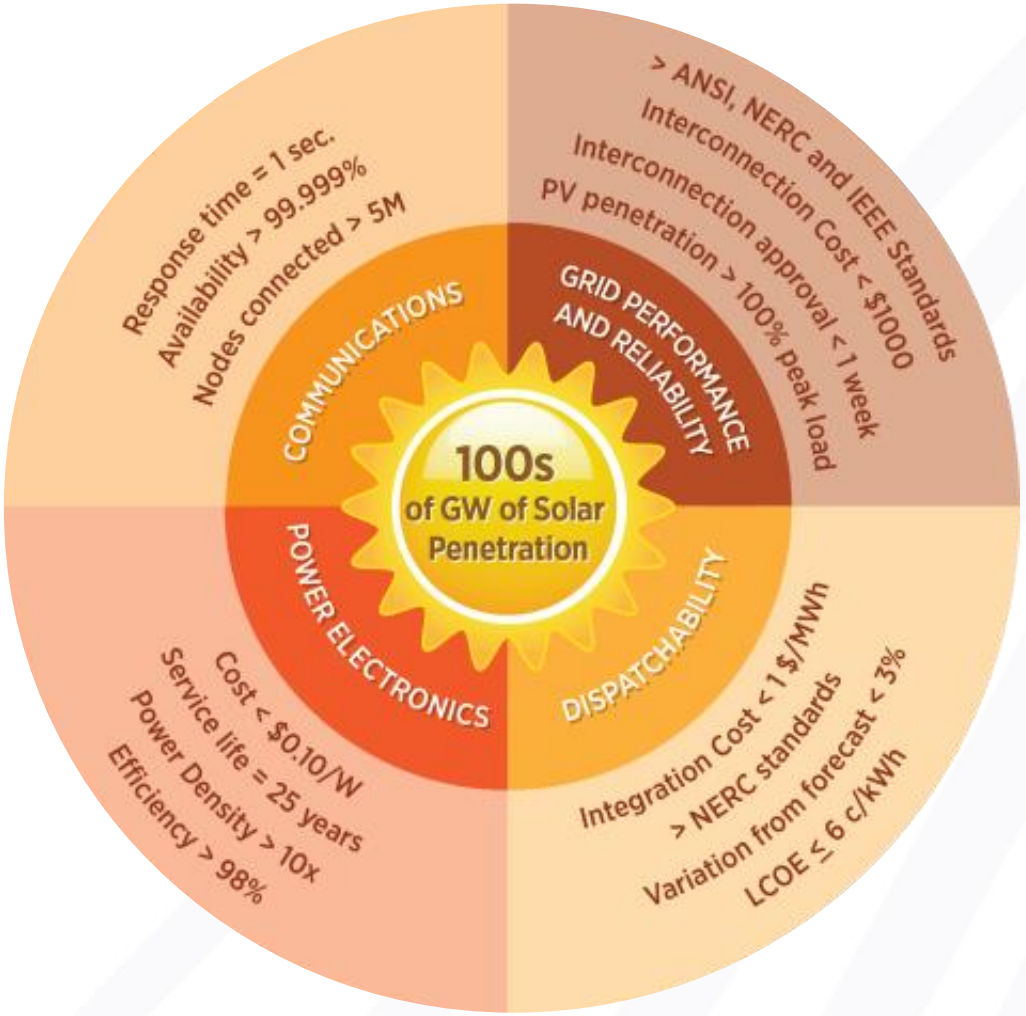
Power Electronics Target Metrics	
Attribute	Target Metric
Conversion Efficiency	> 98%
Service Life and Reliability	> 25 years
Power Density	> 100 W/in^3 for residential and small commercial systems
System Cost	< $0.10/W, utility scale < $0.125/W, commercial scale < $0.15/W, residential scale
Grid-Support Functions	Compliance with ANSI, IEEE, and NERC standards[11]
Interoperability	Compliance with Open Standards which include SunSpec Modbus, Smart Energy Profile (SEP 2), IEC 61850, MultiSpeak, and DNP3



http://energy.gov/eere/sunshot/systems-integration

SunShot U.S. Department of Energy

SunShot Systems Integration



ENERGISE (2016)

SuNLaMP (2015)

SHINES (2015)

SUNRISE (2013)

National Lab R&D (2012)

Hi-Pen (2012)

Plug and Play (2012)

Solar Forecasting (2012)

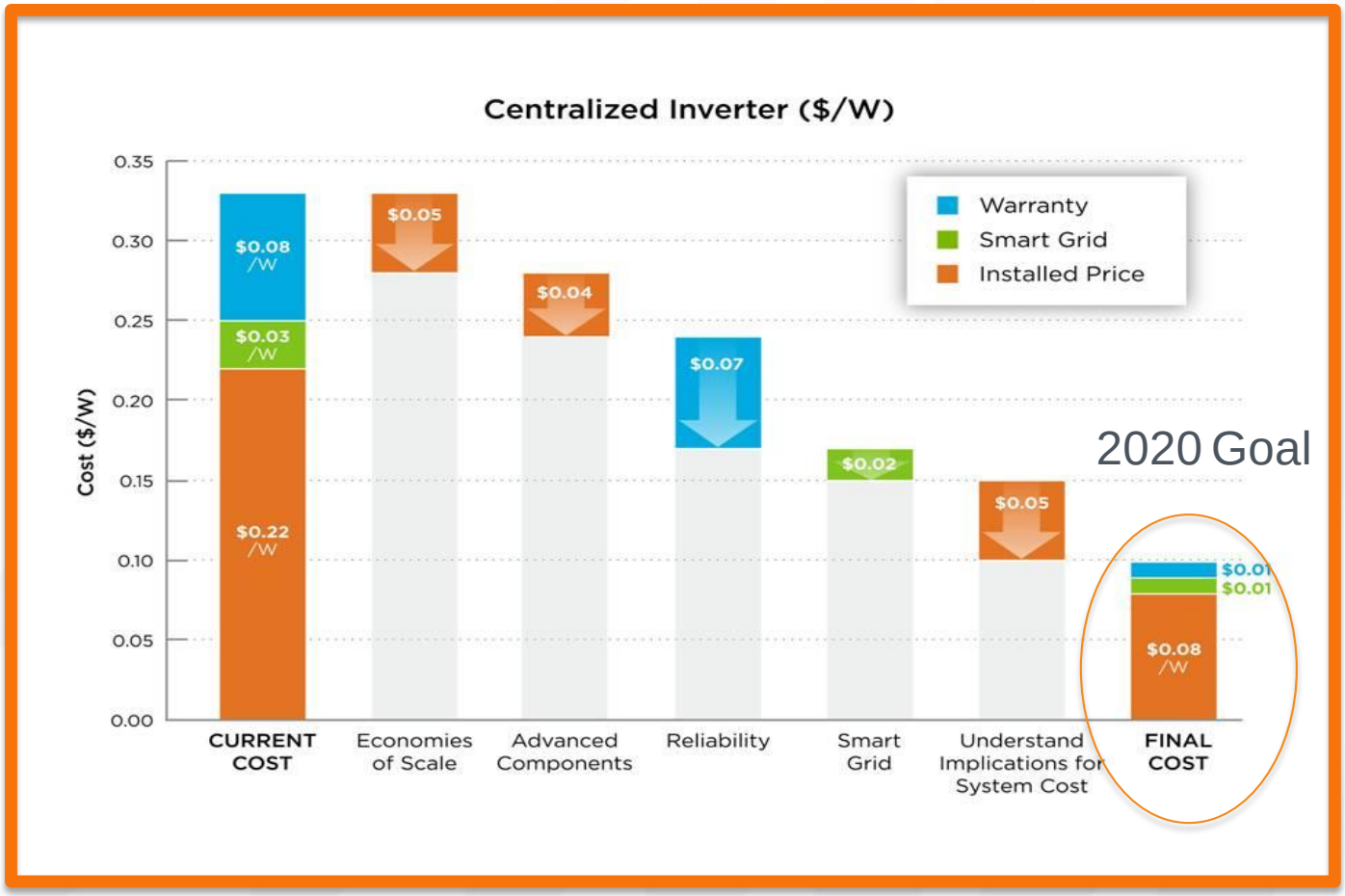
SEGIS-AC (2011)

SunShot
U.S. Department of Energy

Solar Energy Grid Integration Systems – Advanced Concepts

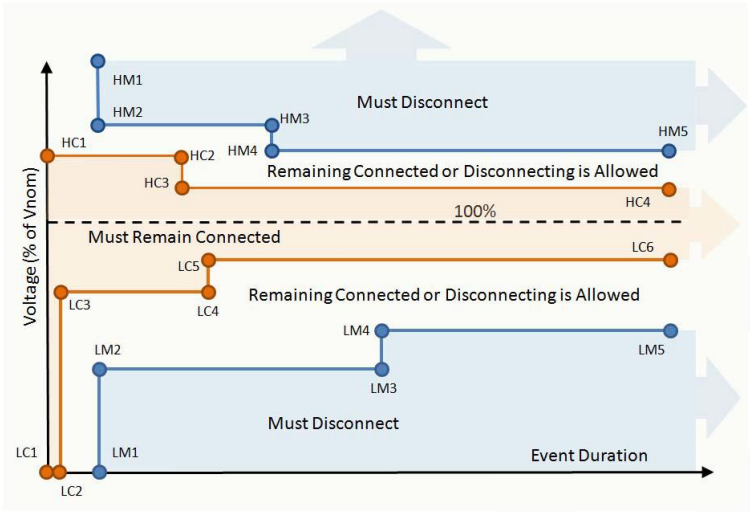
Topic 1: Smart grid functionality that makes it easier to integrate PV solar into the grid

Topic 2: Reduce system cost through innovations in power electronics

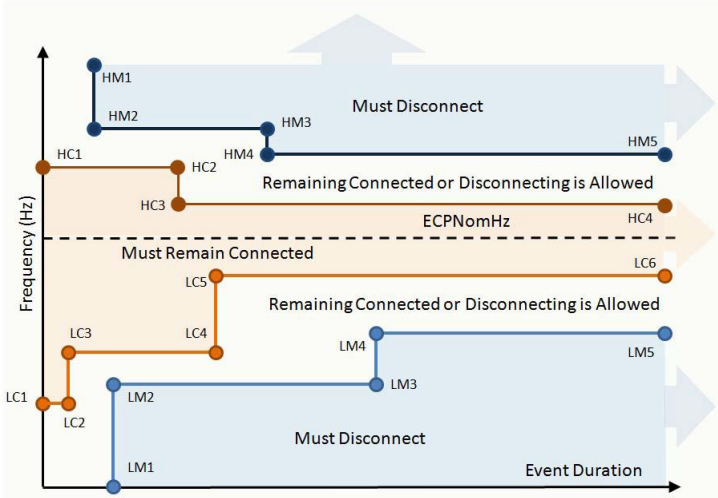


SunShot U.S. Department of Energy

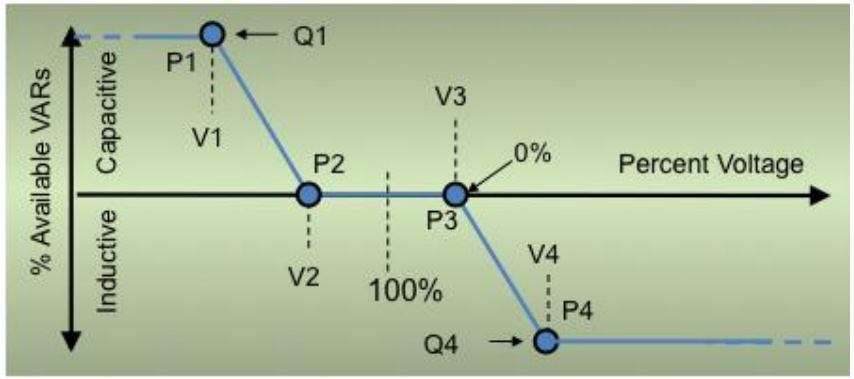
Smart Inverter Functions
(SEGIS-AC)



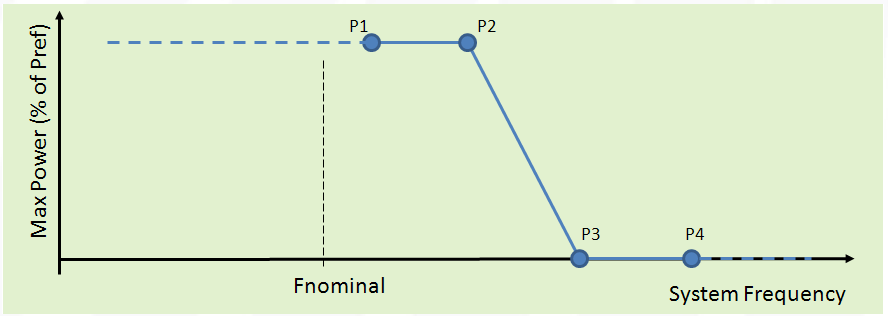
(a) Voltage Ride Through



(b) Frequency Ride Through



(c) Volt/Var



(d) Frequency/Watt

SunShot U.S. Department of Energy

Inverter Lab Testing

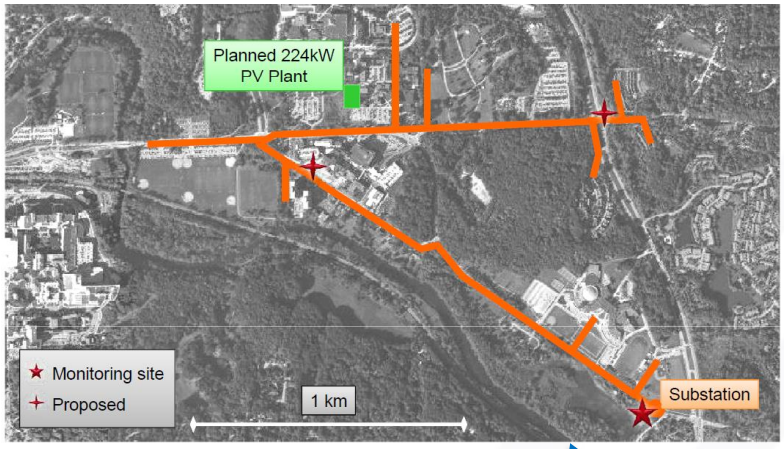
- Manufacturer lab testing
- Power HIL Modeling real feeder topology
- Using real event data

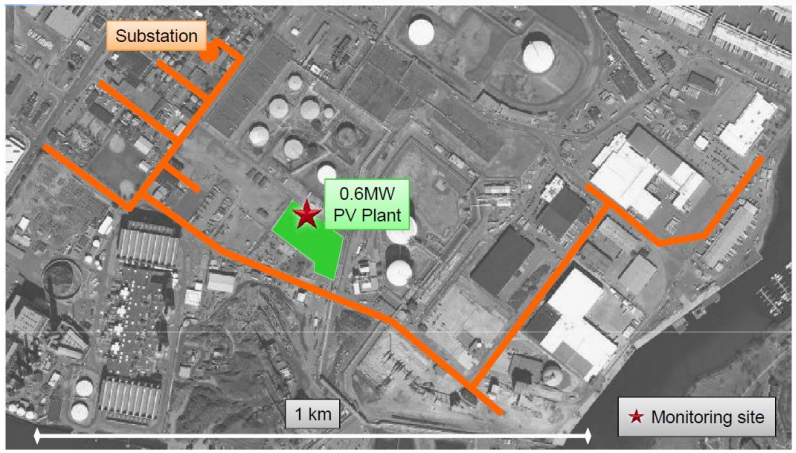
NREL ESIF

- Grid simulator
- PV simulator
- Communication
- Remote control

EPRI Knoxville Lab

Field Demonstration with Utility Partners





- Instrumentation
- Inverter upgrade
- PMC
- Communication
- DERMS software
- Remote control

SunShot U.S. Department of Energy

Power Electronics Design Improvement

Alencon

SunPower/SolarBridge

Delphi

Yaskawa/Solectria

SunShot
U.S. Department of Energy

Power Electronics for Solar

THE NEXT 10 YEARS

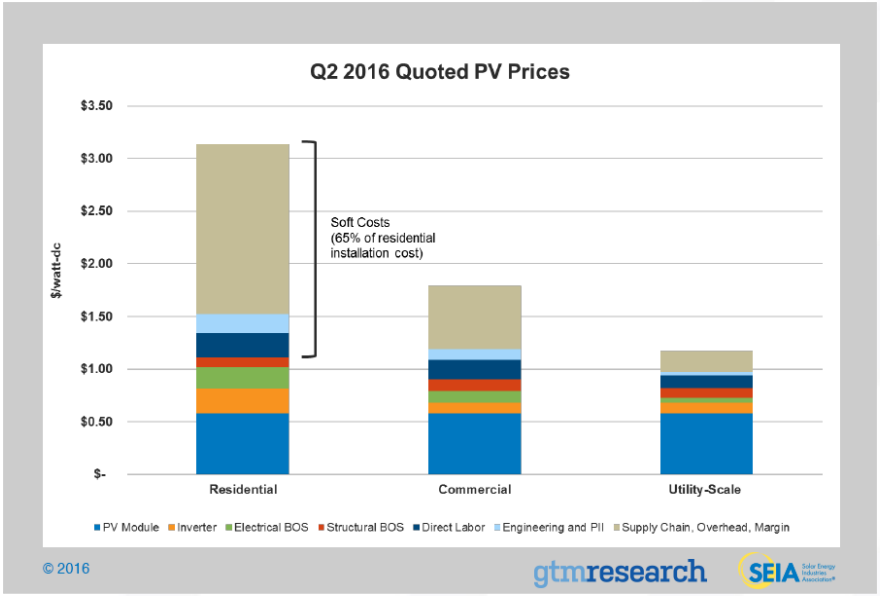
SunShot
U.S. Department of Energy

energy.gov/sunshot

Growth of Solar in the U.S.

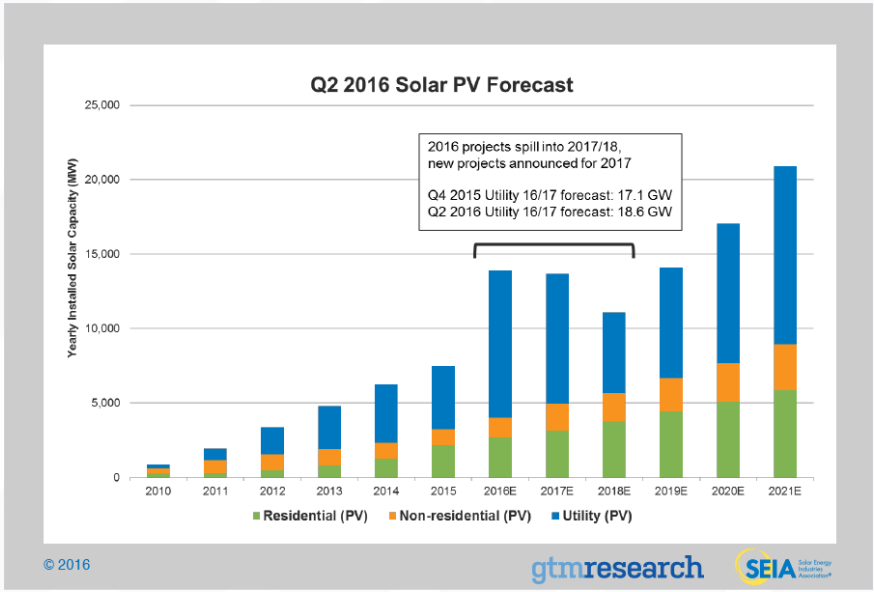
Installed cost of solar system rapidly decreasing

< $1.5/W for utility–scale system



Installed solar generation capacity rapid increasing

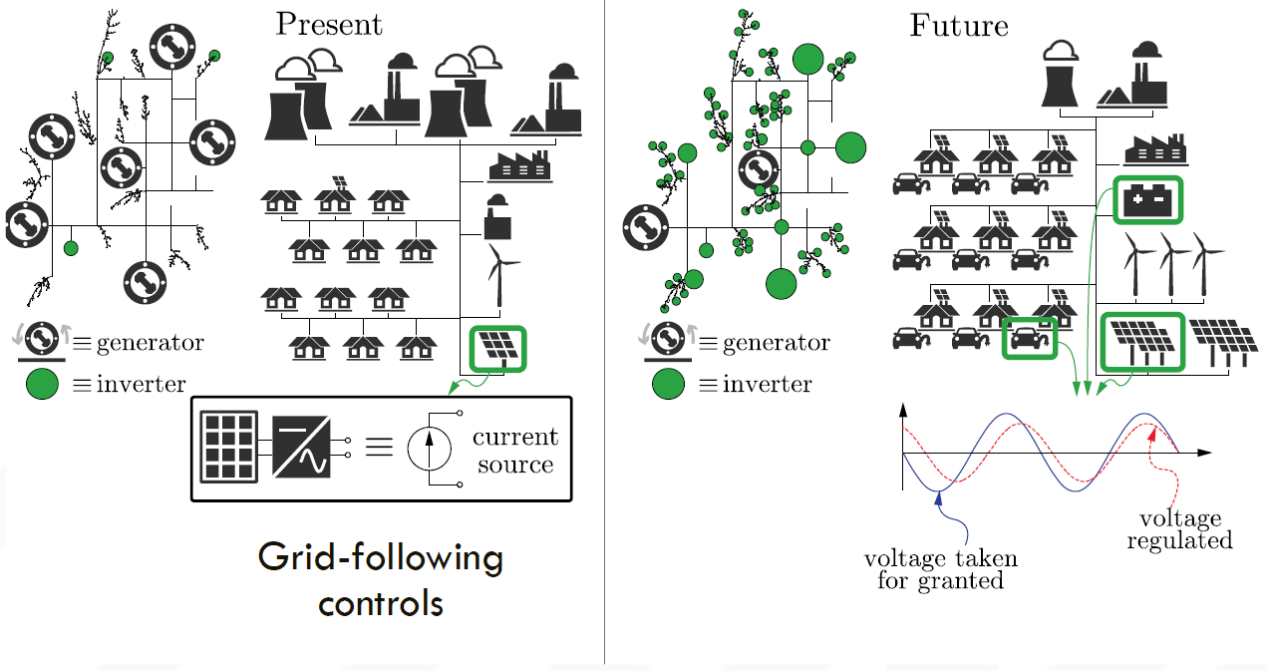
> 40 GW cumulative by 2016 (projected)
> 20 GW annual installation by 2021



SunShot U.S. Department of Energy

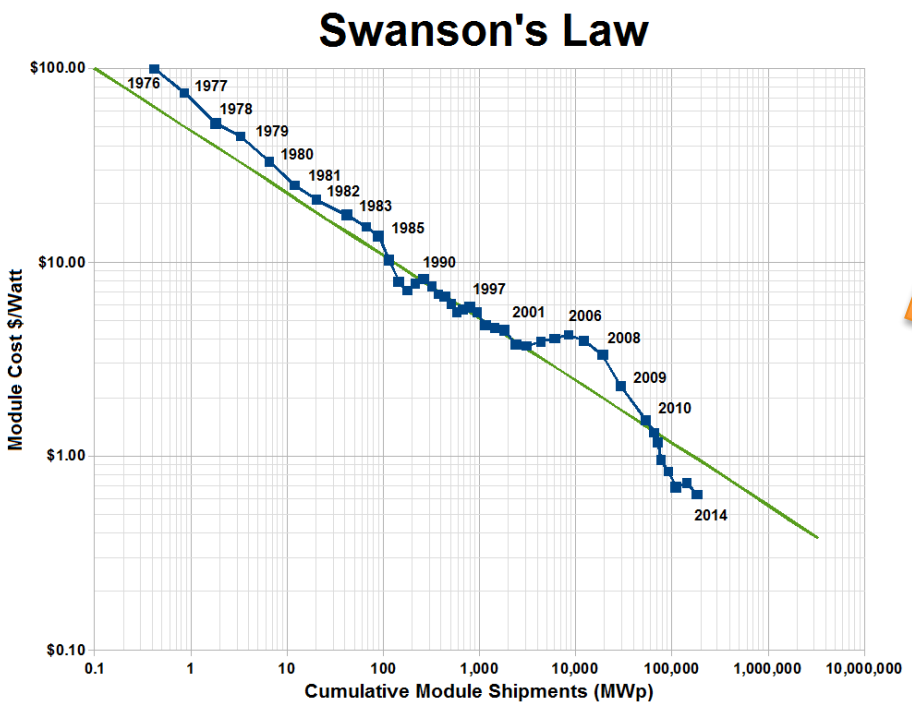
Vision

In 2030, **80%** of electricity could flow through power electronics.



L.M. Tolbert, et al., ORNL Technical Report, 2005.
Brian Johnson, SuNLaMP project

The Learning Curves



the price of solar photovoltaic modules tends to drop 20 percent for every doubling of cumulative shipped volume

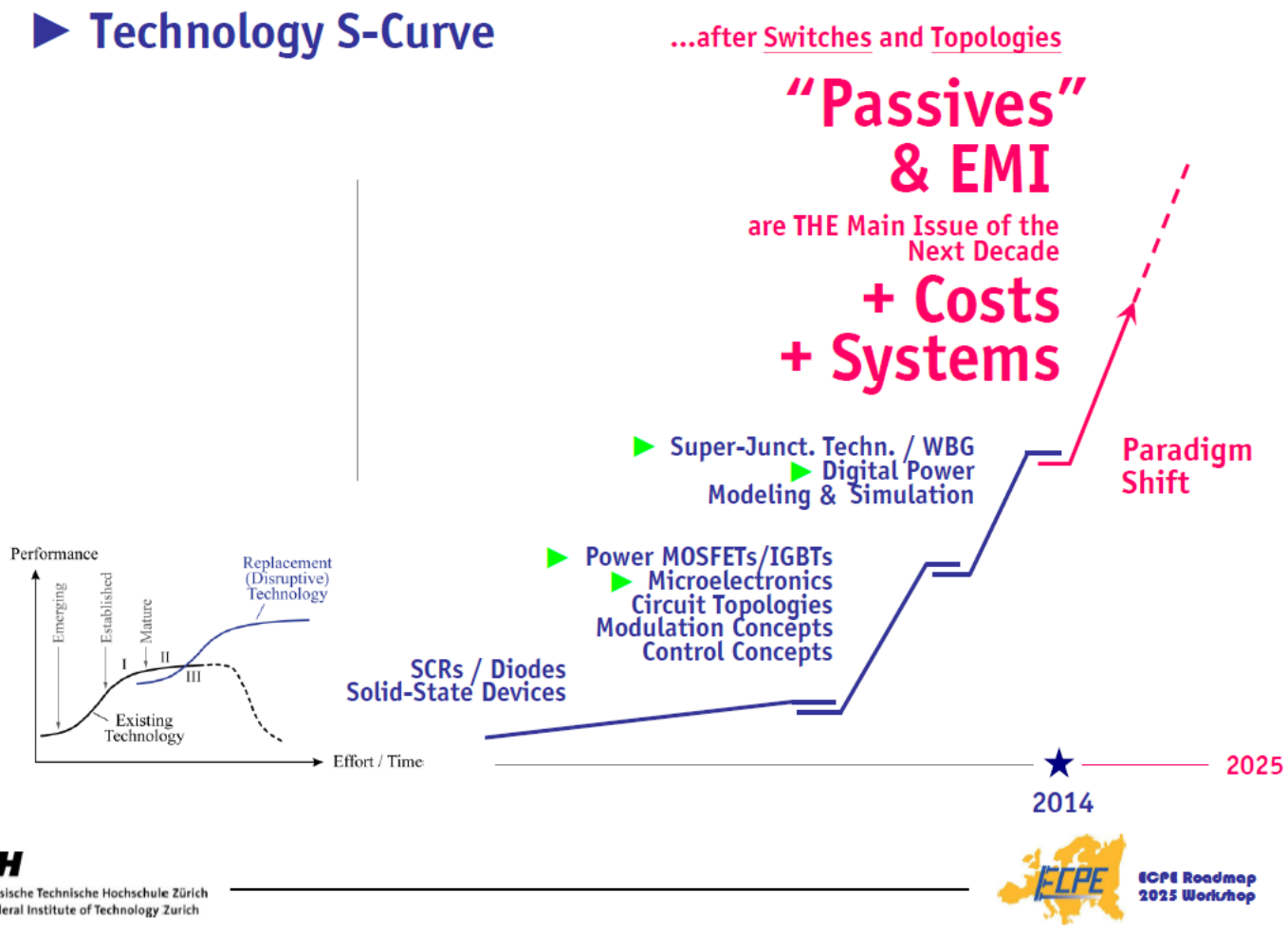
Power Electronics
(More-than-Moore?)

?

SunShot
U.S. Department of Energy

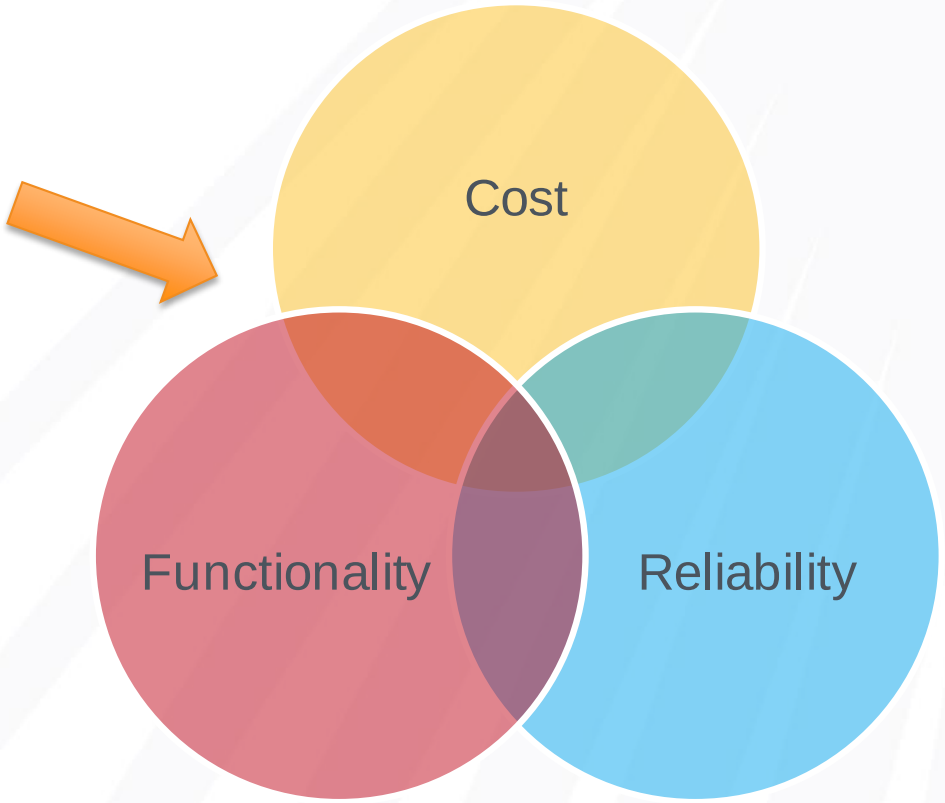
Where are we on the S-Curve?

Johann W. Kolar, "Vision – Power Electronics 2025"



How to Balance Trade-offs

- Manufacturers
- PV developers
- Owners & Operators
- Utilities



Technology Roadmaps

WBG Devices	HF magnetics	Additive Manufacturing
Controls	Thermal Management	Mechanical Design
EMI	Circuit Topology	Passives

PowerAmerica Silicon Carbide Roadmap Drives Long Term Strategy

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
I	AEC-Q101 qual high-I_{DS} chips	175°C is T_{Jmax} for qual	650V – 175A chip @ 90C	1.2kV – 150A chip @ 90C	1.7kV – 125A chip @ 90C	2.4kV – 100A chip @ 90C	3.3kV – 50A chip @ 90C	4.5kV – 40A chip @ 90C	6.5kV – 30A chip @ 90C	6.5kV – 60A IGBT chip @ 90C
V	1.2, 1.7 kV SBD/FET	3.3 kV SBD/ FET	2.4kV SBD/ FET	4.5, 6.5 kV SBD/FET	6.5, 10 kV SBD/FET	6.5kV SBD/ IGBT	10 kV PiN Diode/IGBT	15 kV PiN Diode/IGBT	20 kV PiN Diode/IGBT	30 kV PiN Diode/IGBT
$	1.2 kV FET 40 c/A	1.2 kV FET 30 c/A	1.2 kV FET 25 c/A	1.2 kV FET 20 c/A	1.2 kV FET 15 c/A	1.2 kV FET	1.2 kV FET	1.2 kV FET	1.2 kV FET	1.2 kV FET
App	PFC, PV 5-10 kW	Power Supply	UPS/HVAC/ SSCB	PV 50-250kW, 1.5kV bus	EV Traction	MV VSD Automotive Chargers	Central PV 1-10 MW	DC dis. Data Servers	Wind	Grid power Flow
Frequency / Technology										
	40-100kHz LF DMOS	50-500kHz HF DMOS	40-100kHz HF trench	5-10kHz LF trench	10-30kHz LF/HF trench	5-10kHz LF IGBT	5-10kHz LF IGBT	0.1-1.0MHz HF IGBT	5-10kHz LF IGBT	5-10kHz LF IGBT

Other Questions For Workshop Discussions

- What are most critical challenges and research priorities?
- How do we leverage other industries – wind, automotive, energy storage, and industrial motors?
- How to bridge the gap between technology potentials and commercial successes?

SunShot
U.S. Department of Energy

Thank You!

& Let's work together!

STAY UPDATED and sign up for our e-newsletter
@energy.gov/sunshot