Photovoltaics II

Conversion of light to electricity

Energy
ITP / NYU / Feddersen

Previously

For later:

Balance of system
Tracking methods
Concentrating systems
Solar lighting
Solar thermal

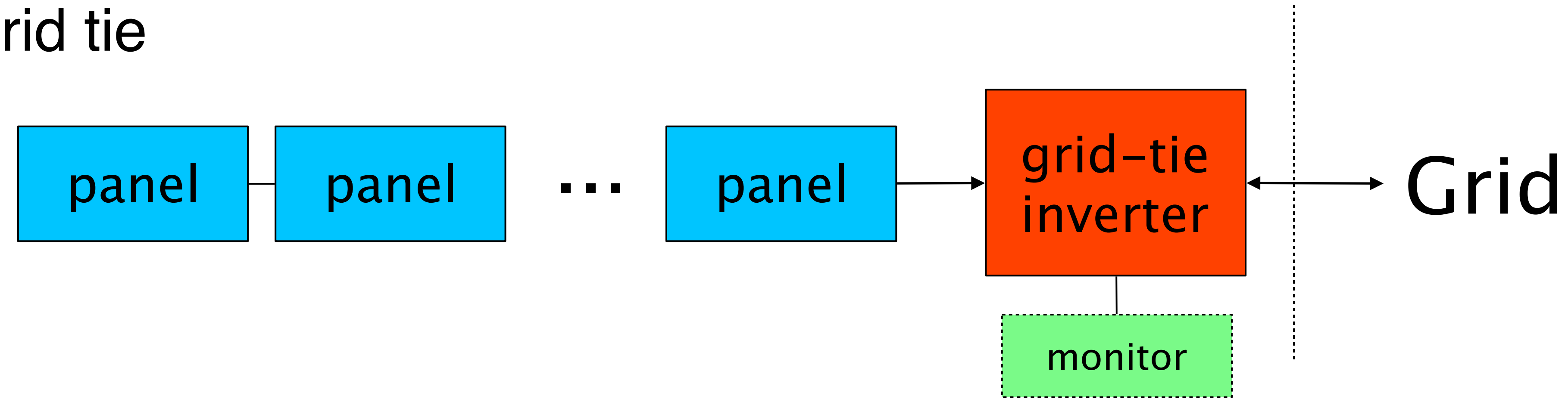
also:
Kardashev scale
Space based solar power
Dyson swarms

Balance of system
Tracking methods
Concentrating systems
Solar lighting
Solar thermal

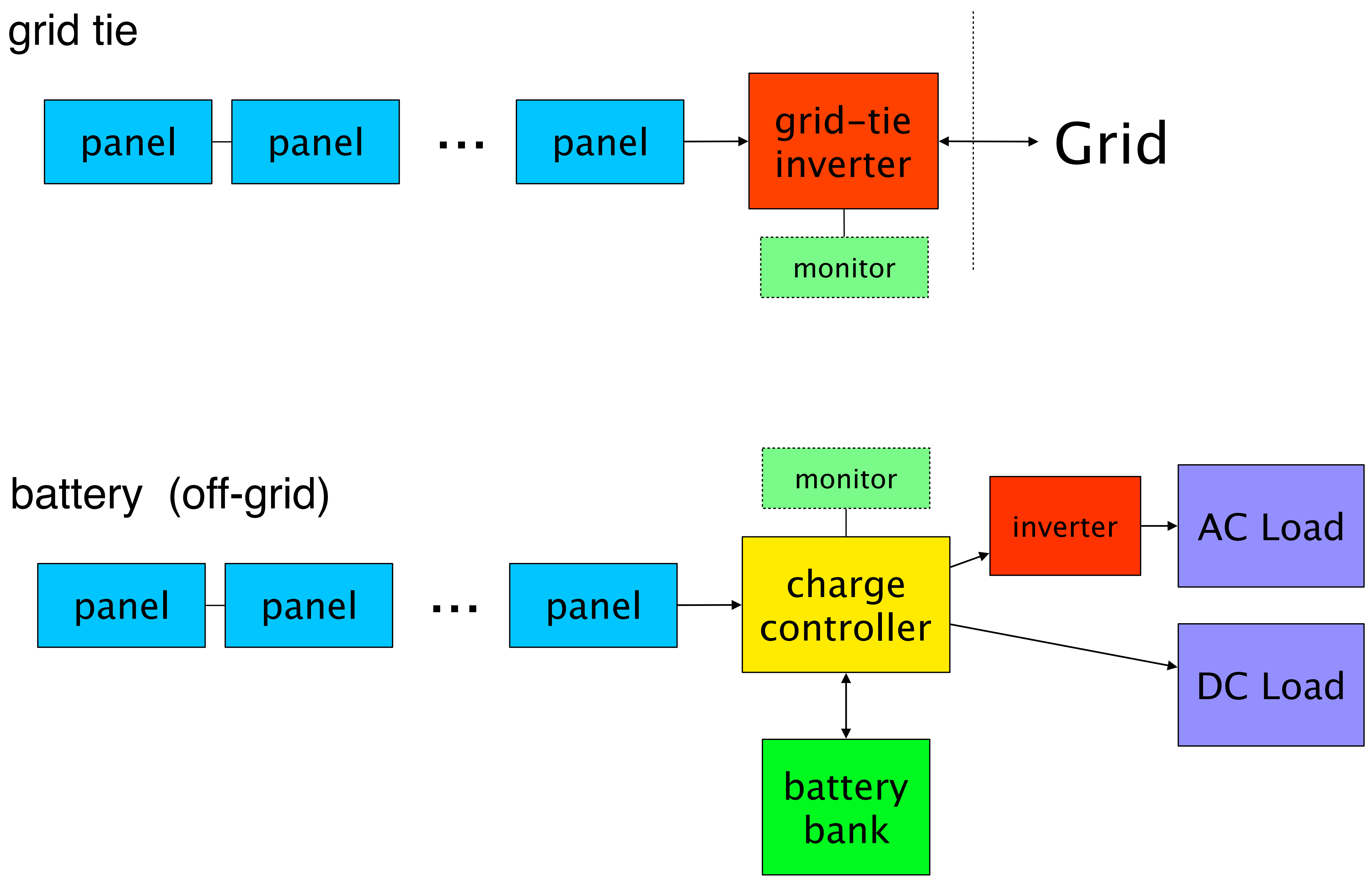
also:
Kardashev scale
Space based solar power
Dyson swarms

Balance of system: grid tie

grid tie



Balance of system: grid tie vs. battery




Balance of system:
grid-tie inverter
Inverters at “Riverhouse”
Battery Park City

Balance of system: grid-tie inverter

SMA Solar Technology | SMA America | SMA Websites | Search

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Home > Products > Grid-Tied Inverters > SUNNY BOY > SUNNY BOY 5000-US / 6000-US / 7000-US / 8000-US

SUNNY BOY 5000-US / 6000-US / 7000-US / 8000-US

Versatile performer with UL certification

The Sunny Boy 5000-US, 6000-US, 7000-US and 8000-US inverters are UL certified and feature excellent efficiency. Graduated power classes provide flexibility in system design. Automatic grid voltage detection* and an integrated DC disconnect switch simplify installation, ensuring safety as well as saving time. These models feature galvanic isolation and can be used with all types of modules-crystalline as well as thin-film.

Extended operating temperature range to -40 °C available. Please specify when ordering.

* US Patent US7352549B1

INTEGRATED AFCI

WHERE TO BUY

Overview | Technical data | Downloads

	Sunny Boy 5000-US	Sunny Boy 6000-US	Sunny Boy 7000-US	Sunny Boy 8000-US
Input (DC)	**208 V AC 240 V AC 277 V AC**	**208 V AC 240 V AC 277 V AC**	**208 V AC 240 V AC 277 V AC**	**240 V AC 277 V AC**
Max. recommended PV power (@ module STC)	6250 W	7500 W	8750 W	10000 W
Max. DC power (@ cos φ = 1)	5300 W	6350 W	7400 W	8600 W
Max. DC voltage	600 V	600 V	600 V	600 V
DC nominal voltage	310 V	310 V	310 V	345 V
MPP voltage range	250 V – 480 V	250 V – 480 V	250 V – 480 V	300 V – 480 V
Min. DC voltage / start voltage	250 V / 300 V	250 V / 300 V	250 V / 300 V	300 V / 365 V
Max. input current / per string (at DC disconnect)	21 A / 20 A 36 A @ combined terminal	25 A / 20 A 36 A @ combined terminal	30 A / 20 A 36 A @ combined terminal	30 A / 20 A 36 A @ combined terminal
Number of MPP trackers / fused strings per MPP tracker	1 / 4 (DC disconnect)	1 / 4 (DC disconnect)	1 / 4 (DC disconnect)	1 / 4 (DC disconnect)
Output (AC)				
AC nominal power	5000 W	6000 W	7000 W	7680 W 8000 W
Max. AC apparent power	5000 VA	6000 VA	7000 VA	7680 VA 8000 VA
Nominal AC voltage / adjustable	208 V / yes 240 V / yes 277 V / yes	208 V / yes 240 V / yes 277 V / yes	208 V / yes 240 V / yes 277 V / yes	240 V / yes 277 V / yes
AC voltage range	183 – 229 V 211 – 264 V 244 – 305 V	183 – 229 V 211 – 264 V 244 – 305 V	183 – 229 V 211 – 264 V 244 – 305 V	211 – 264 V 244 – 305 V

Inverters at “Riverhouse”
Battery Park City


charge controller
battery
inverter
AC load
Balance of system:
battery system

MORNINGSTAR

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Morningstar Corporation • Product Selector

Product Selector

Please use filters on the right side to search for products.

Inverters

SureSine

SI-300-115V (60 Hz)
SI-300-115V-UL (60 Hz)
SI-300-220V (50 Hz)

MPPT Charge Controllers

TriStar MPPT 600V

TriStar MPPT

TS-MPPT-45
TS-MPPT-60

SunSaver MPPT

SS-MPPT-15L

Product Selector

Type of regulation

Solar Current

Load Current

Load Control

Meter Option Available?

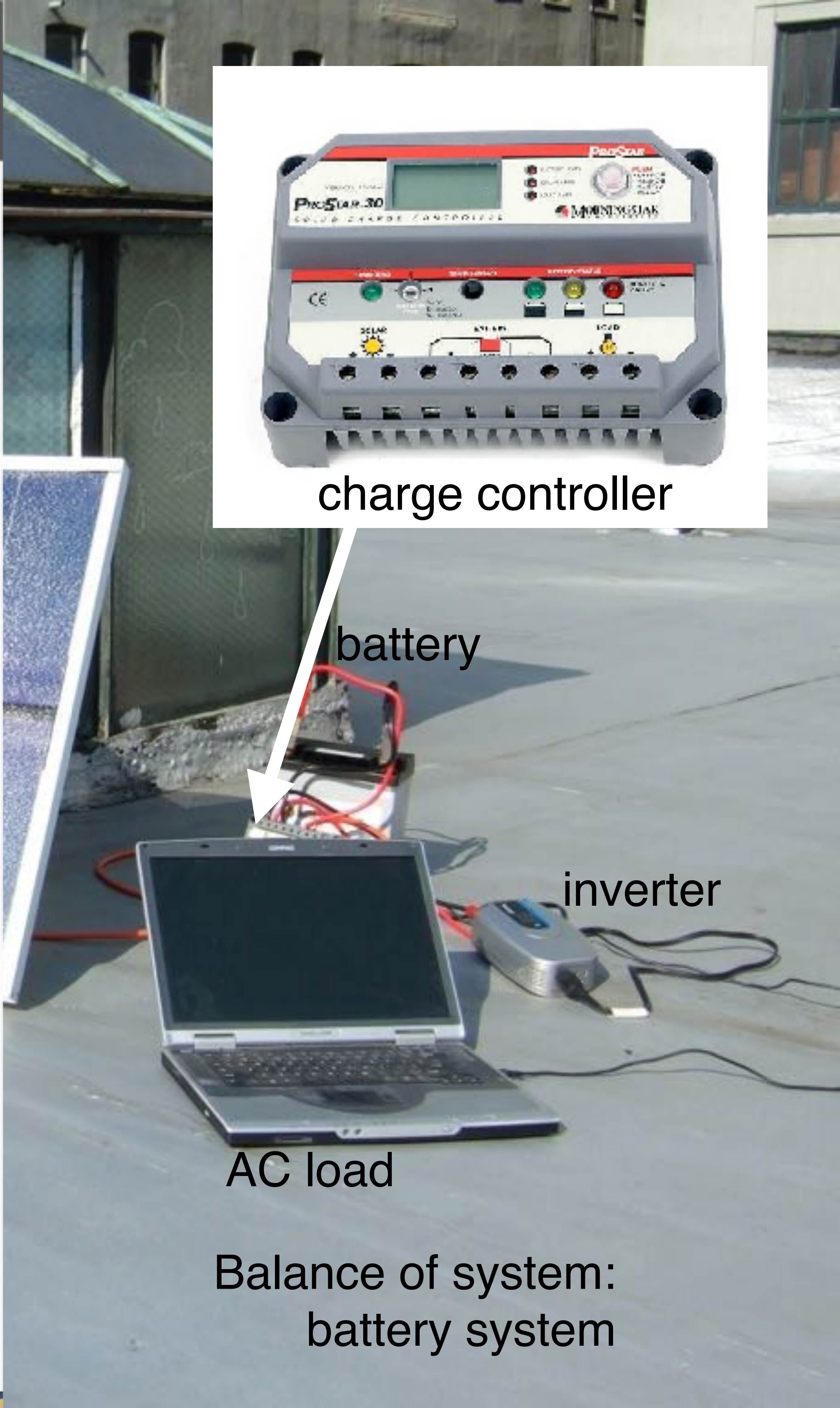
Data Port Available?

Battery System Voltage

☐ 12 ☐ 24 ☐ 36 ☐ 48 ☐ 8 ☐ 8-64

Submit

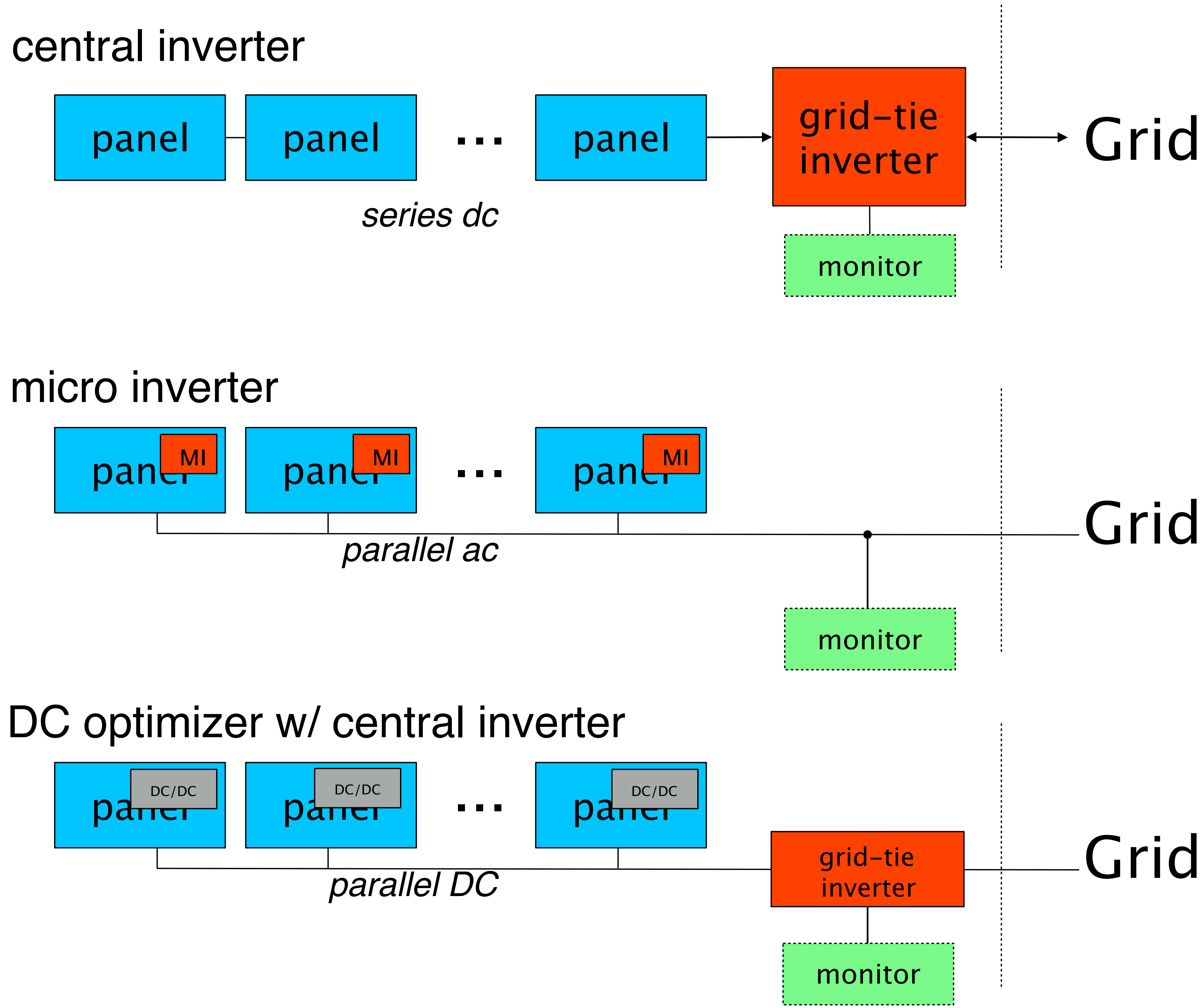
http://www.morningstarcorp.com/product-selector/



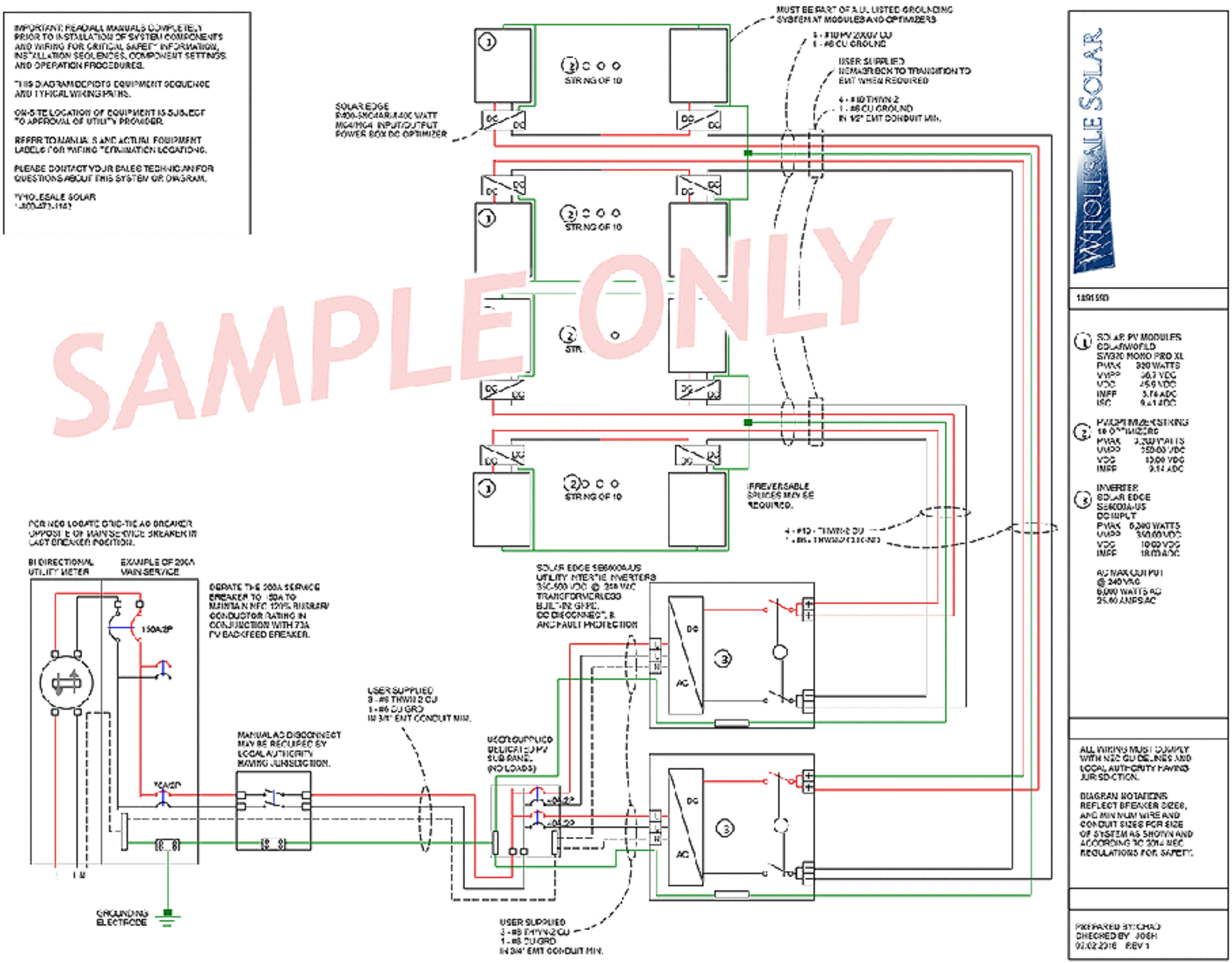
Balance of system:
battery system


BATTERY STATUS
AC OUTLETS
FAULT
POWER
inverter
AC load
battery
xPower 1500
Portable Household Power
XANTREX
Balance of system:
battery system

Balance of system: grid tie (traditional) vs. micro inverters vs. DC optimizers



Balance of system:
micro inverter


IMPORTANT: READ ALL MANUALS COMPLETELY PRIOR TO INSTALLATION OF SYSTEM COMPONENTS AND WIRING FOR CRITICAL SAFETY INFORMATION, INSTALLATION SEQUENCES, COMPONENT SETTINGS, AND OPERATION PROCEDURES.
THIS DIAGRAM DEPICTS EQUIPMENT SEQUENCE AND TYPICAL WIRING PATHS.
ON-SITE LOCATION OF EQUIPMENT IS SUBJECT TO APPROVAL OF UTILITY PROVIDER.
REFER TO MANUALS AND ACTUAL EQUIPMENT LABELS FOR WIRING TERMINATION LOCATIONS.
PLEASE CONTACT YOUR SALES TECHNICIAN FOR QUESTIONS ABOUT THIS SYSTEM OR DIAGRAM.
WHOLESALE SOLAR
MUST BE PART OF A UL LISTED GROUNDING SYSTEM AT MODULES AND OPTIMIZERS
USER SUPPLIED
STRING OF 10
SOLAR EDGE
POWER BOX DC OPTIMIZER
SAMPLE ONLY
IRREVERSABLE SPLICES MAY BE REQUIRED.
BI DIRECTIONAL UTILITY METER
EXAMPLE OF 200A MAIN SERVICE
150A/2P
MANUAL AC DISCONNECT MAY BE REQUIRED BY LOCAL AUTHORITY HAVING JURISDICTION.
USER SUPPLIED DEDICATED PV SUB-PANEL (NO LOADS)
GROUNDING ELECTRODE
DC
AC
WHOLESALE SOLAR
SOLAR PV MODULES
SOLARWORLD
SW320 MONO PRO XL
PMAX 320 WATTS
PV OPTIMIZER STRING
10 OPTIMIZERS
INVERTER
SOLAR EDGE
SE6000A-US
DC INPUT
AC MAX OUTPUT
@ 240 VAC
6,000 WATTS AC
25.00 AMPS AC
ALL WIRING MUST COMPLY WITH NEC GUIDELINES AND LOCAL AUTHORITY HAVING JURISDICTION.
DIAGRAM NOTATIONS REFLECT BREAKER SIZES, AND MINIMUM WIRE AND CONDUIT SIZES FOR SIZE OF SYSTEM AS SHOWN AND ACCORDING TO 2014 NEC REGULATIONS FOR SAFETY.
CHECKED BY JOSH
REV 1

Balance of system:
micro inverter

Balance of system: micro inverter

40 MW goal

PSE&G Installed Solar Projects	Location	Size MW-dc	Service Date
Pole-attached solar units	Statewide	26.92	as of February 1, 2012
PSE&G Trenton Solar Farm	Trenton, NJ	1.26	September, 2010
Barringer High School	Newark, NJ	0.65	October, 2010
Central High School	Newark, NJ	0.50	October, 2010
Park Avenue Elementary School	Newark, NJ	0.51	October, 2010
PSE&G Silver Lake Solar Farm	Edison, NJ	2.02	November, 2010
Camden St. Schools	Newark, NJ	0.91	December, 2010
PSE&G Edison Training & Development	Edison, NJ	0.71	December, 2010
CenterPoint Properties	Bayonne, NJ	1.75	December, 2010
PSE&G Linden Solar Farm	Linden, NJ	3.20	December, 2010
PSE&G Central Division Headquarters	Somerset, NJ	0.92	December, 2010
PSE&G Yardville Solar Farm	Hamilton TWP, NJ	4.30	February, 2011
Matrix Realty Building A	Perth Amboy, NJ	1.69	February, 2011
Matrix Realty Building B	Perth Amboy, NJ	1.17	February, 2011
Matrix Realty	South Brunswick, NJ	2.98	June, 2011
Rider University	Lawrenceville, NJ	0.74	October, 2011
Mills Creek	Burlington TWP, NJ	3.82	November, 2011
Kearny Landfill Solar	Kearny, NJ	3.00	December, 2011
Thorofare Solar Farm	West Depford, NJ	0.72	December, 2011
Summit Associates	Edison, NJ	2.22	December, 2011
TOTAL PSE&G		**59.99 MW-dc**	
GRAND TOTAL Installed		86.60 MW-dc	

Balance of system: micro inverter

40 MW goal, currently 39.75

PSE&G Installed Solar Projects	Location	Size MW-dc	Service Date
Pole-attached solar units	Statewide	26.92	as of February 1, 2012
PSE&G Trenton Solar Farm	Trenton, NJ	1.26	
Barringer High School	Newark, NJ	0.65	
Central High School	Newark, NJ	0.50	
Park Avenue Elementary School	Newark, NJ	0.51	
PSE&G Silver Lake Solar Farm	Edison, NJ	2.02	
Camden St. Schools	Newark, NJ	0.91	
PSE&G Edison Training & Development	Edison, NJ	0.71	
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Mills Creek	Burlington TWP, NJ	3.82	
Kearny Landfill Solar	Kearny, NJ	3.00	
Thorofare Solar Farm	West Depford, NJ	0.72	
Summit Associates	Edison, NJ	2.22	
TOTAL PSE&G		**59.99 MW-dc**	
GRAND TOTAL Installed		86.60 MW-dc	

PSE&G Installed Solar Projects	Location	Size MW-dc	Service Date
Pole-attached solar units	Statewide	36.50	as of March 2013
Barringer High School	Newark, NJ	0.65	October, 2010
PSE&G Linden Solar Farm	Linden, NJ	3.20	December, 2010
PSE&G Central Division Headquarters	Somerset, NJ	0.92	December, 2010
PSE&G Yardville Solar Farm	Hamilton TWP, NJ	4.30	February, 2011
Matrix Realty Building A	Perth Amboy, NJ	1.69	February, 2011
Matrix Realty Building B	Perth Amboy, NJ	1.17	February, 2011
Matrix Realty	South Brunswick, NJ	2.98	June, 2011
Rider University	Lawrenceville, NJ	0.74	October, 2011
Mills Creek	Burlington TWP, NJ	3.82	November, 2011
Kearny Landfill Solar	Kearny, NJ	3.00	December, 2011
Thorofare Solar Farm	West Depford, NJ	0.72	December, 2011
Summit Associates	Edison, NJ	2.22	December, 2011
Black Rock/Matrix Realty	South Brunswick	2.97	March, 2012
PSE&G Metro Division Headquarters	Clifton, NJ	0.73	July 1, 2012
Community Food Bank of NJ	Hillside, NJ	1.07	August 2012
Hackensack Solar Farm	Hackensack, NJ	1.06	Winter 2012
TOTAL PSE&G		**75.40 MW-dc**	

PSE&G Installed Solar Projects	Location	Size MW-dc	Service Date
Pole-attached solar units	Statewide	39.75	as of January 2014
Trenton Solar Farm	Trenton, NJ	1.26	September, 2010
Barringer High School	Newark, NJ	0.65	October, 2010

Balance of system:
micro inverter

NJ total installed PV capacity surpassed 1GW in February 2013

http://www.nj.gov/bpu/pdf/announcements/2013/20130319.pdf

Text As of 2018: 3.2GW

http://www.njcleanenergy.com/renewable-energy/project-activity-reports/project-activity-reports

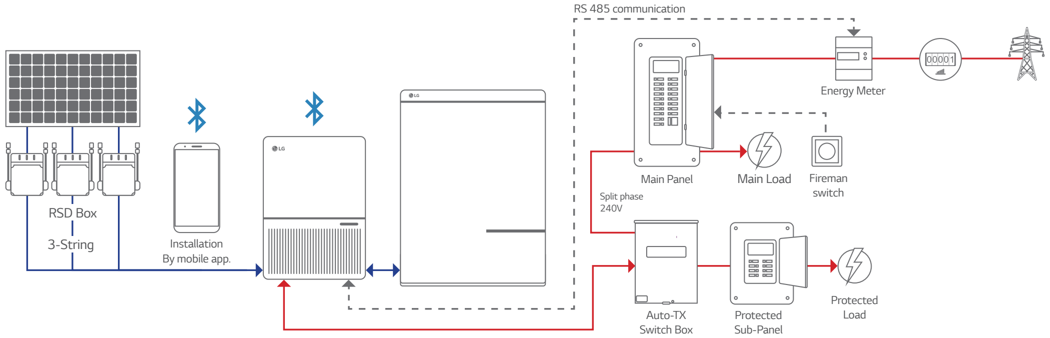
Specification

The LG ESS is provided as an integrated energy storage system, complete with PCS, ATS and Energy Meter. In the case of a DC-coupled system, RSD will also be included. For either the AC or DC-coupled system, a second battery pack is optional.

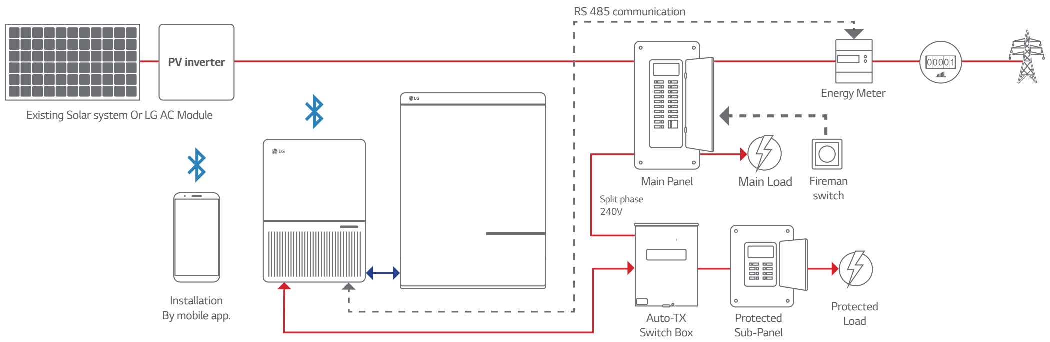
LG ESS PCS | Primary Battery | Auto-Transfer Switch | Energy Meter | Rapid Shutdown Box for NEC 2014 | Secondary Battery

The LG ESS is offered as both an AC-coupled solution and a DC-coupled solution. The 7.6kW DC-coupled product offers unparalleled solar + storage performance, allowing homeowners to seamlessly store excess solar energy to power their home both day and night. The 5kW AC-coupled product can be easily added to an existing solar system, offering a reliable and cost-effective way to manage Time of Use (TOU) rates and provide backup power.

DC 7.6kW



AC 5kW



Contact

Jan Dominguez | ESS Sales Engineer
LG Electronics USA Inc.
910 Sylvan Avenue, Englewood Cliffs, NJ 07632
O : (201).408.9065 | M : (310).626.3427 | jan.dominguez@lge.com

LG

The LG ESS

The Evolution of Home Energy Storage

10 yrs Warranty

The LG Electronics ESS is a state-of-the-art home energy management system designed for homeowners ready to take control of their home energy usage. The LG ESS is offered in both an AC-coupled and DC-coupled configuration. The 7.6kW DC-coupled solution with an integrated high efficiency PV inverter is well suited for new solar PV + storage installations. The 5kW AC-coupled solution is ideal for customers looking to install an ESS in a home with an existing solar system.
The 7.6kW DC-coupled product offers unparalleled solar + storage performance, allowing homeowners to seamlessly store excess solar energy to power their home both day and night. The 5kW AC-coupled product can be easily added to an existing solar system, offering a reliable and cost-effective way to manage Time of Use (TOU) rates and provide backup power.
Product features include quick and easy installation, a compact and elegant design, and an integrated smart energy management system (EMS). The EMS enables customers to control their electric bill through self-consumption of solar and TOU rate smart scheduling, and includes an off-grid mode to protect the customer's home in the event of a power outage.

Features at a glance

Easy Two-Person Installation
All required components included for complete install ; Painless commissioning via Auto Self-Check

High Efficiency PCS
97.5%
Achieving 97.5% CEC Efficiency ; Multi-String & MPPTs for multi-angled roof

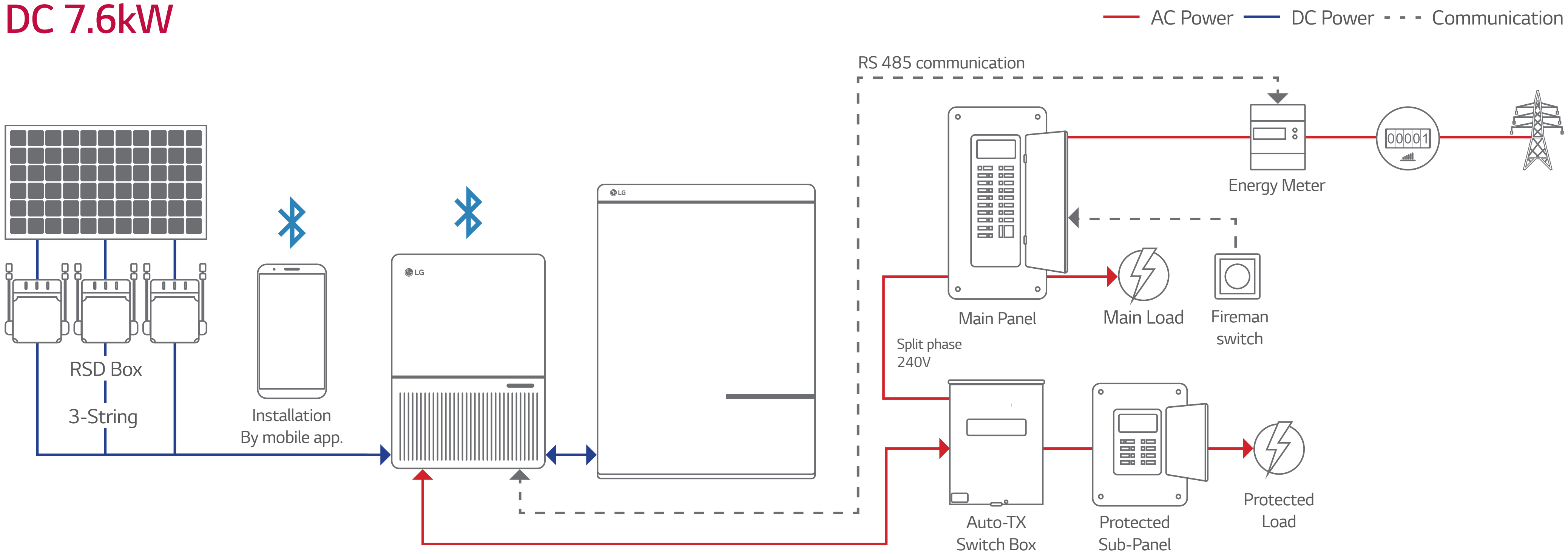
Extremely Reliable Battery and Scalable
Up to 19.6kWh for longer back-up time ; Compatible with LG Chem RESU 10H

Smart Energy Management and Remote System Monitoring
Emergency Back-up ; 24-7 energy monitoring

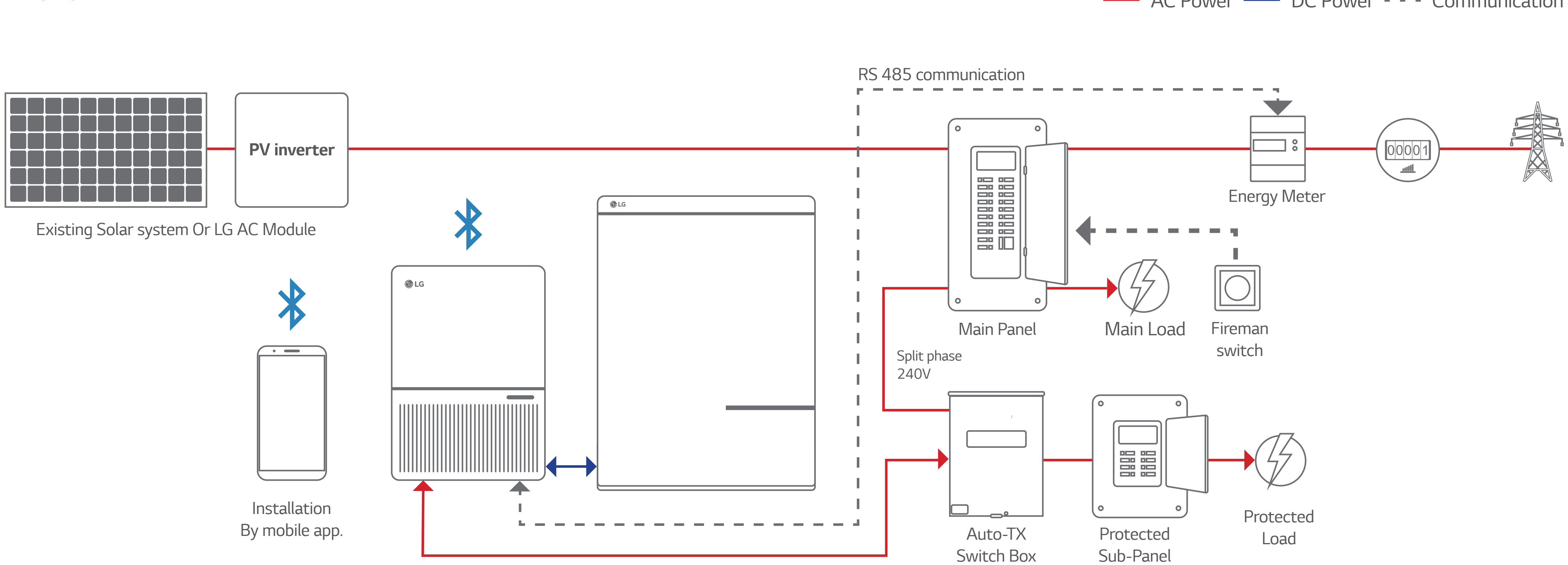
One-stop service & 10-Year Warranty
10 YEAR WARRANTY
ESS can be paired with LG PV modules for a single provider for all warranty issues

LG

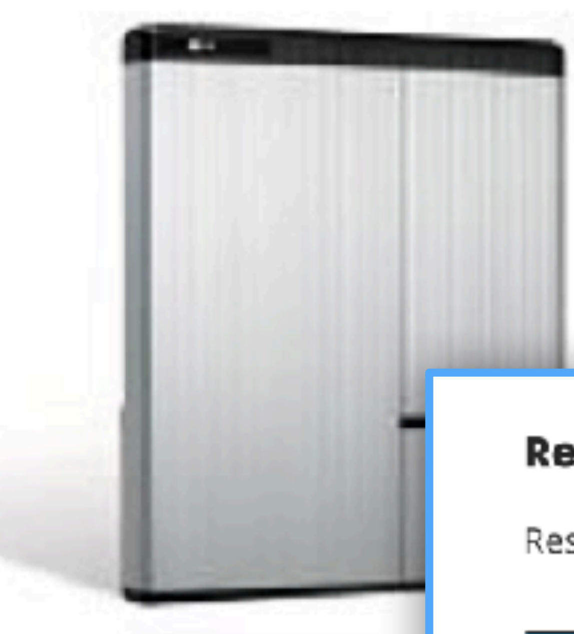
DC 7.6kW



AC 5kW



~$1000/kWh stored electricity



LG CHEM RESU10H-SEG 400VDC 9.8 KWH PRIMARY LITHIUM-ION BATTERY

by LG CHEM

Be the first to review this item

Price: $7,600.00 & **FREE Shipping**

Get $70 off instantly: Pay $7,530.00 upon approval for the Amazon Prime Rewards Visa Card.

Note: Not eligible for Amazon Prime.

- Battery Type: Lithium-Ion
- Voltage: 400 V
- 5 Hour: Capacity: 10.0
- Warranty: 10-years

$7,600.00

& **FREE Shipping**

Get it Wed, Mar 20 - Wed, Mar 27

Only 1 left in stock - order soon.

$7,600.00 + Free Shipping

Add to Cart

Buy Now

Ships from and sold by THE 1976 WHOLESALE COMPANY GROUP.

Deliver to Jeff - Montclair 07042

Add to List

Share

Other Sellers on Amazon

$7,800.00 Add to Cart

Residential

Residential Time Periods and Delivery Rates*

	Peak	Off-Peak
Hours	8 a.m. to Midnight	Midnight to 8 a.m.
TIME-OF-USE DELIVERY RATES		
June 1 to Sept 30	21.80 cents/kWh	1.54 cents/kWh
All other months	8.07 cents/kWh	1.54 cents/kWh
STANDARD DELIVERY RATES	First 250 kWh	Over 250 kWh
June 1 to Sept 30	10.221 cents/kWh	11.749 cents/kWh
All other months	10.221 cents/kWh	10.221 cents/kWh

Stores about ~$2 worth of peak electricity

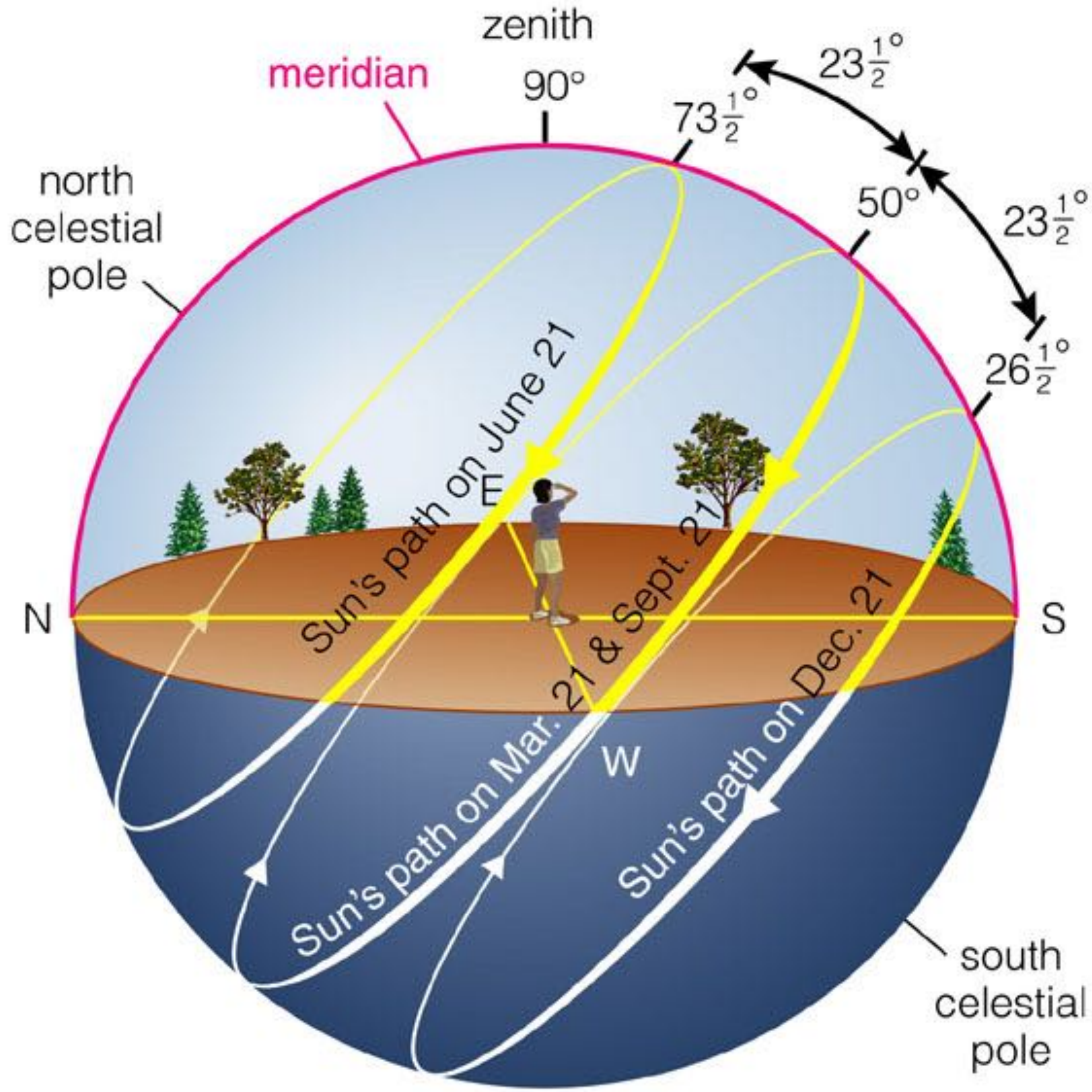
Related to solar, especially batteries:

- “DR” - Demand Response
- Demand Charges (typically commercial customers)
- Time of Use electricity rates
- Tiered Electricity Rates

Balance of system
Tracking methods
Concentrating systems
Solar lighting
Solar thermal

also:
Kardashev scale
Space based solar power
Dyson swarms


FOR 37°-43° N LAT
SOLAR TIME
SOLAR PATHFINDER
THE ENERGY EVALUATOR


zenith
meridian
90°
$73\frac{1}{2}$°
$23\frac{1}{2}$°
50°
$23\frac{1}{2}$°
$26\frac{1}{2}$°
north
celestial
pole
Sun's path on June 21
E
Sun's path on Mar. 21 & Sept. 21
Sun's path on Dec. 21
N
S
W
south
celestial
pole


Tracking
single axis
(elevation)


Tracking
~10kW
single axis
(azimuth)


Tracking
dual axis
~10kW


Tracking
dual axis
elevation axis
azimuth axis


Tracking
dual axis - mixed
“Riverhouse” BPC
azimuth
east and west sides
elevation
south side

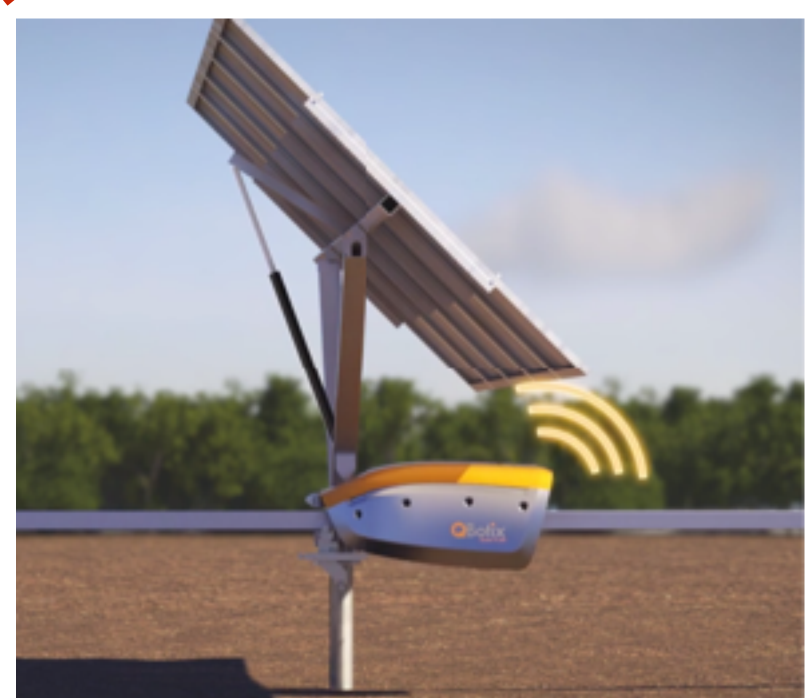
Challenge:

Tracking systems 1) require **space between arrays** and 2) introduce **mechanical parts** that require energy and maintenance.

Cost of tracking system must compete with cost of simply adding more fixed panels.

Ways to simplify mechanics or minimize number of actuators are interesting.

QBotix RIP 2015



Balance of system
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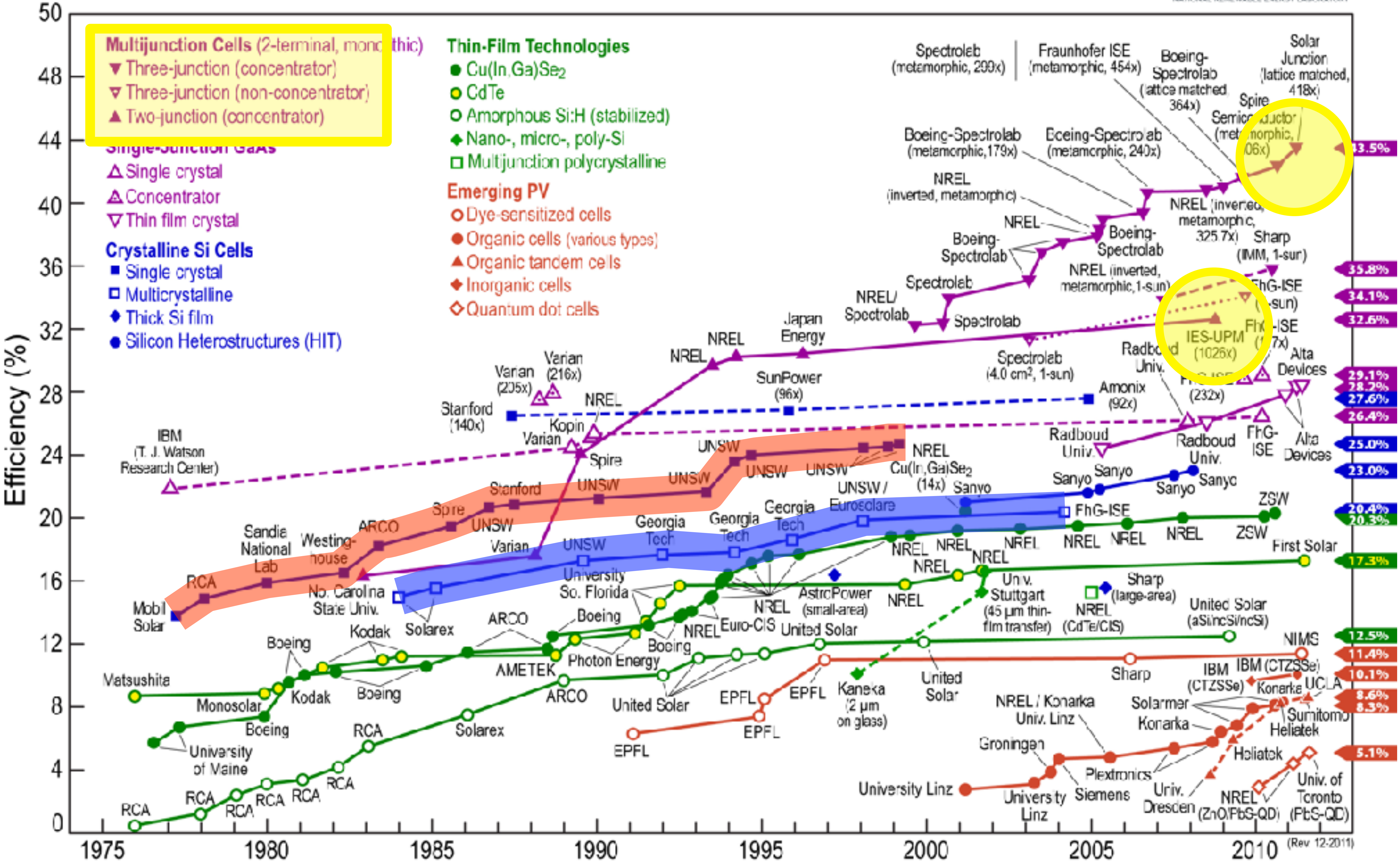
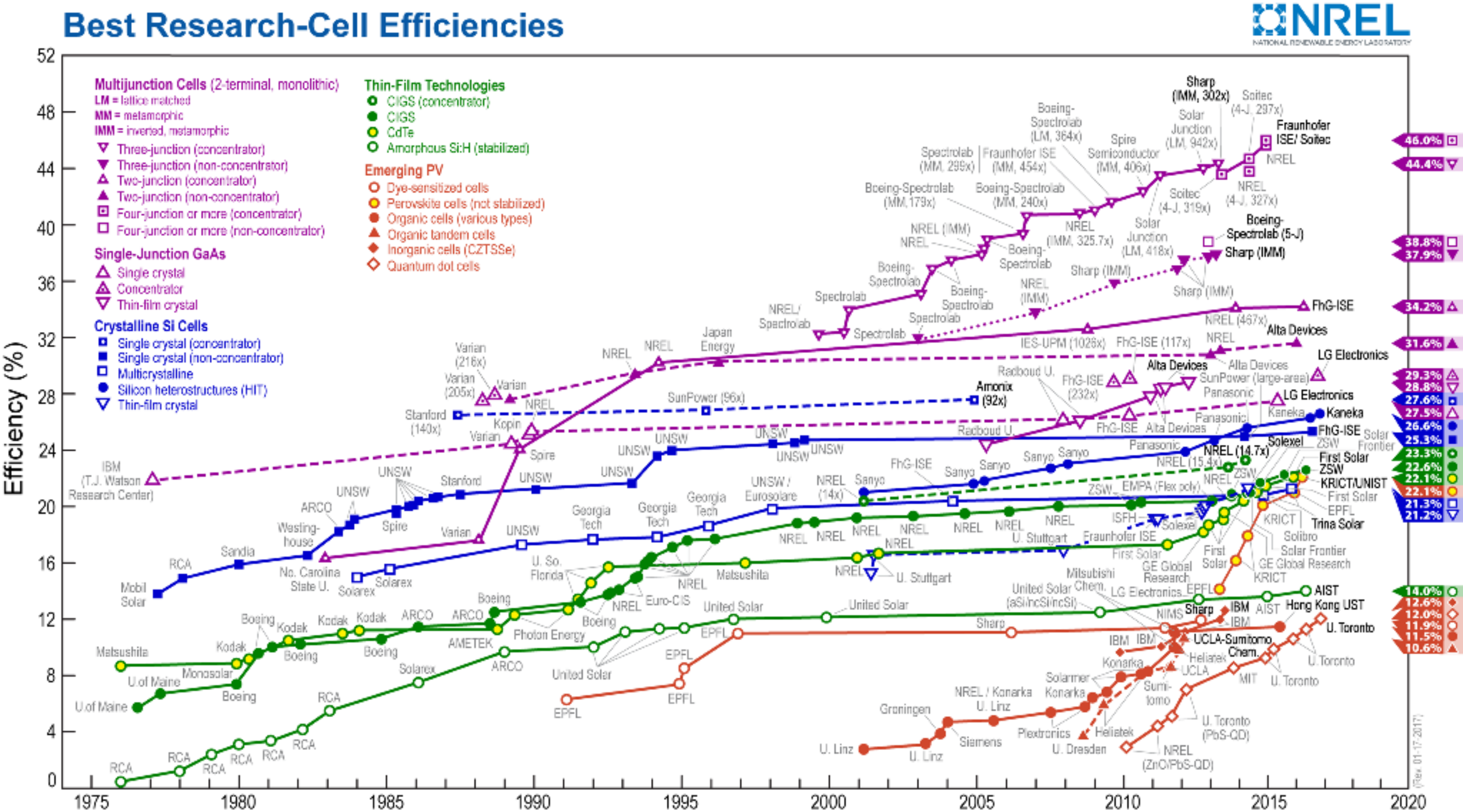
Best Research-Cell Efficiencies



Source: DOE NREL



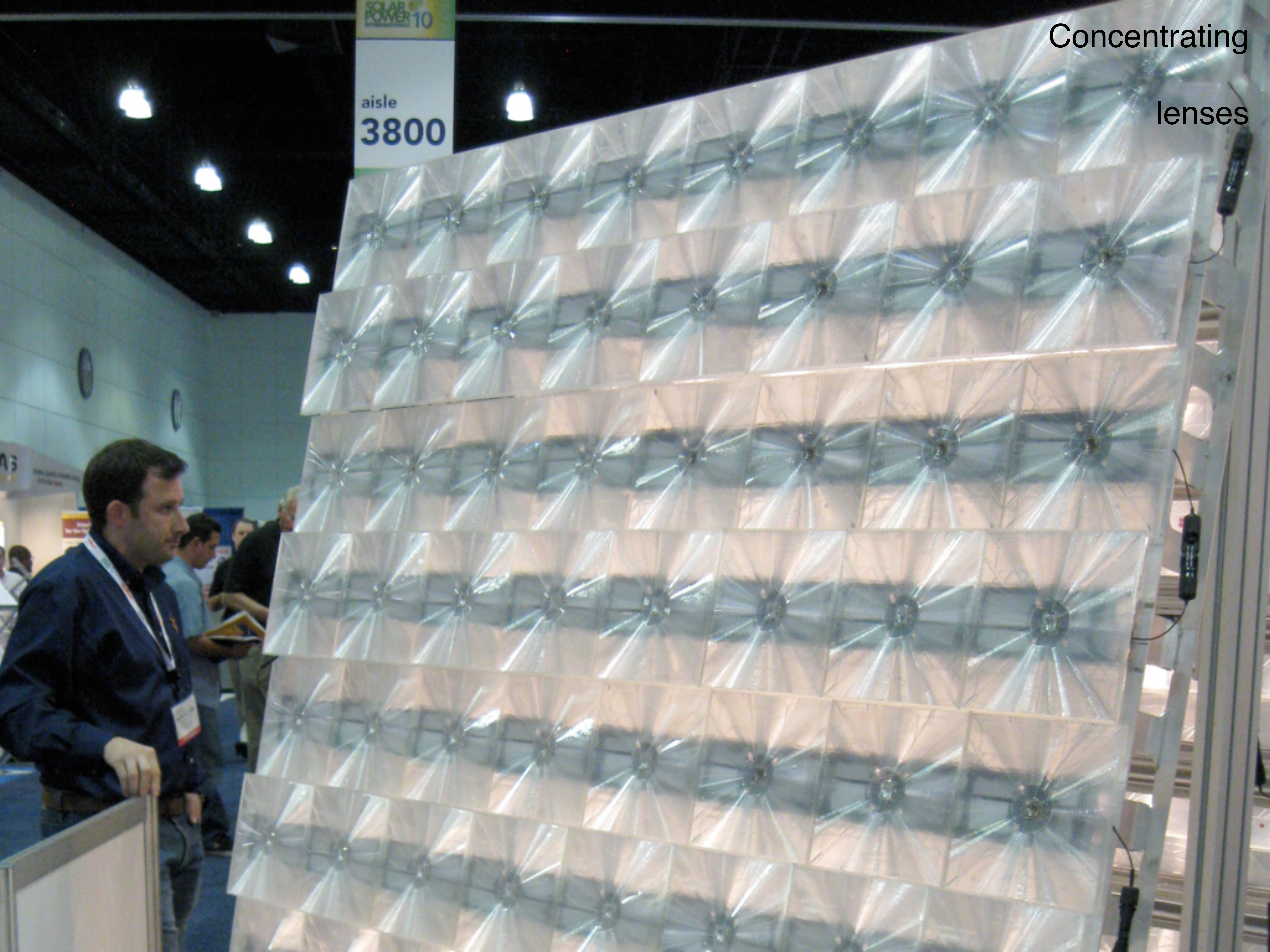
2017

Source: DOE NREL

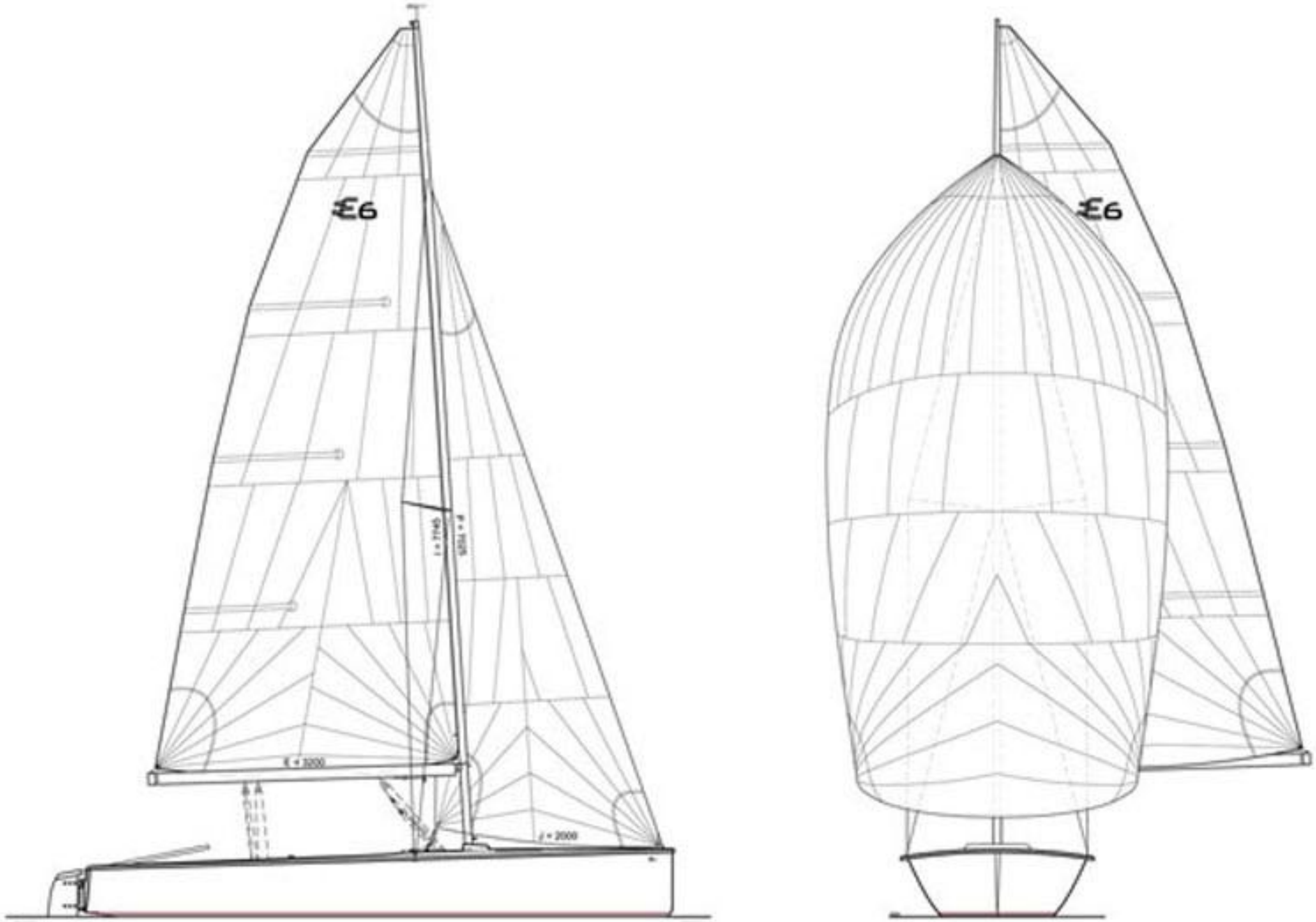

Concentrating
mirrors
Energy Innovations
RIP 2015
WOOD & JONES

Concentrating

cheap mirrors



Concentrating lenses


J = 2000

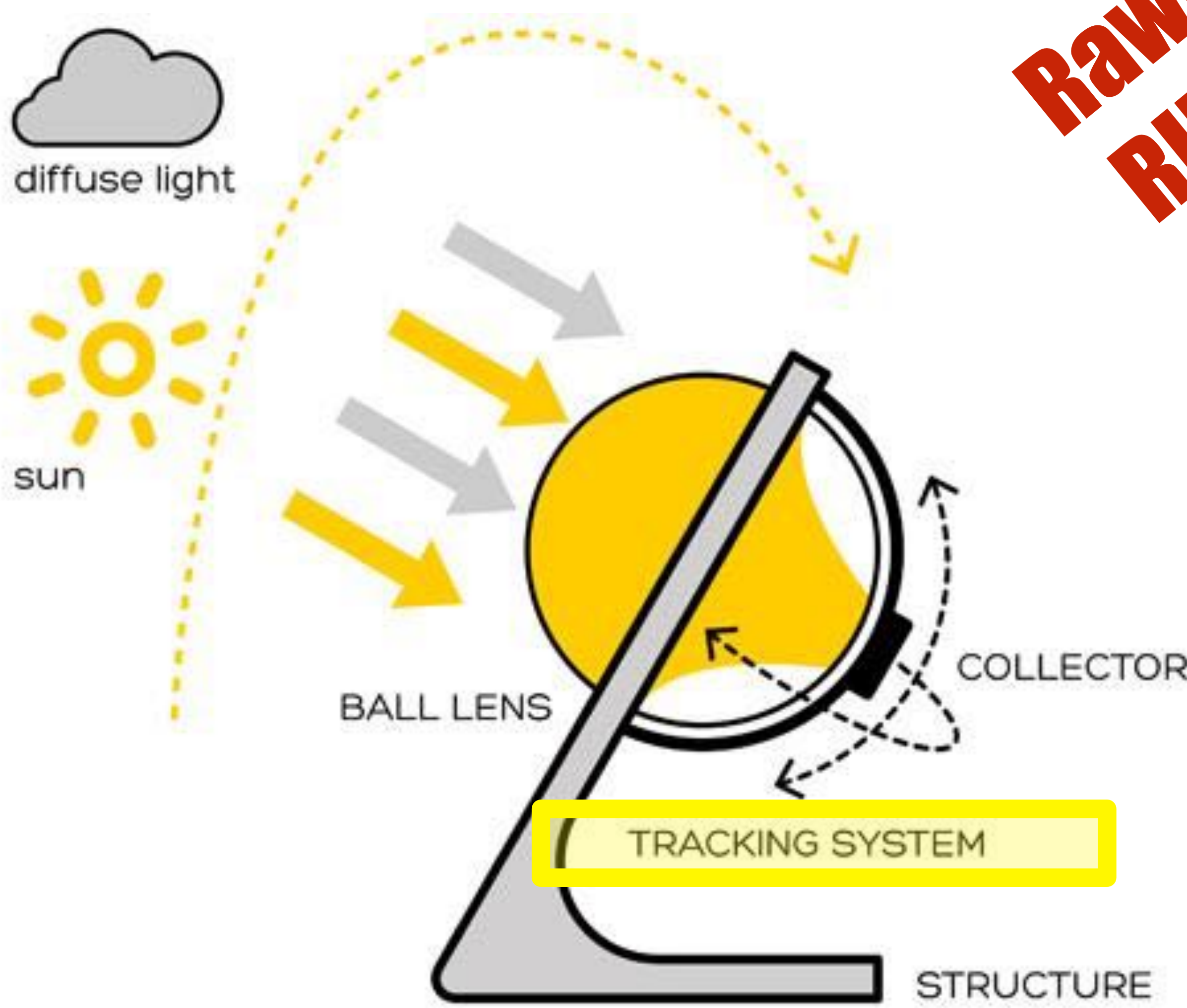
Concentrating

spherical
lenses

Challenge:

Concentrating systems also require tracking systems, so same issues (**space between arrays** and **mechanical parts**) apply. Concentrated sunlight can reach very high temperatures and could focus on surrounding structures if tracking system fails.

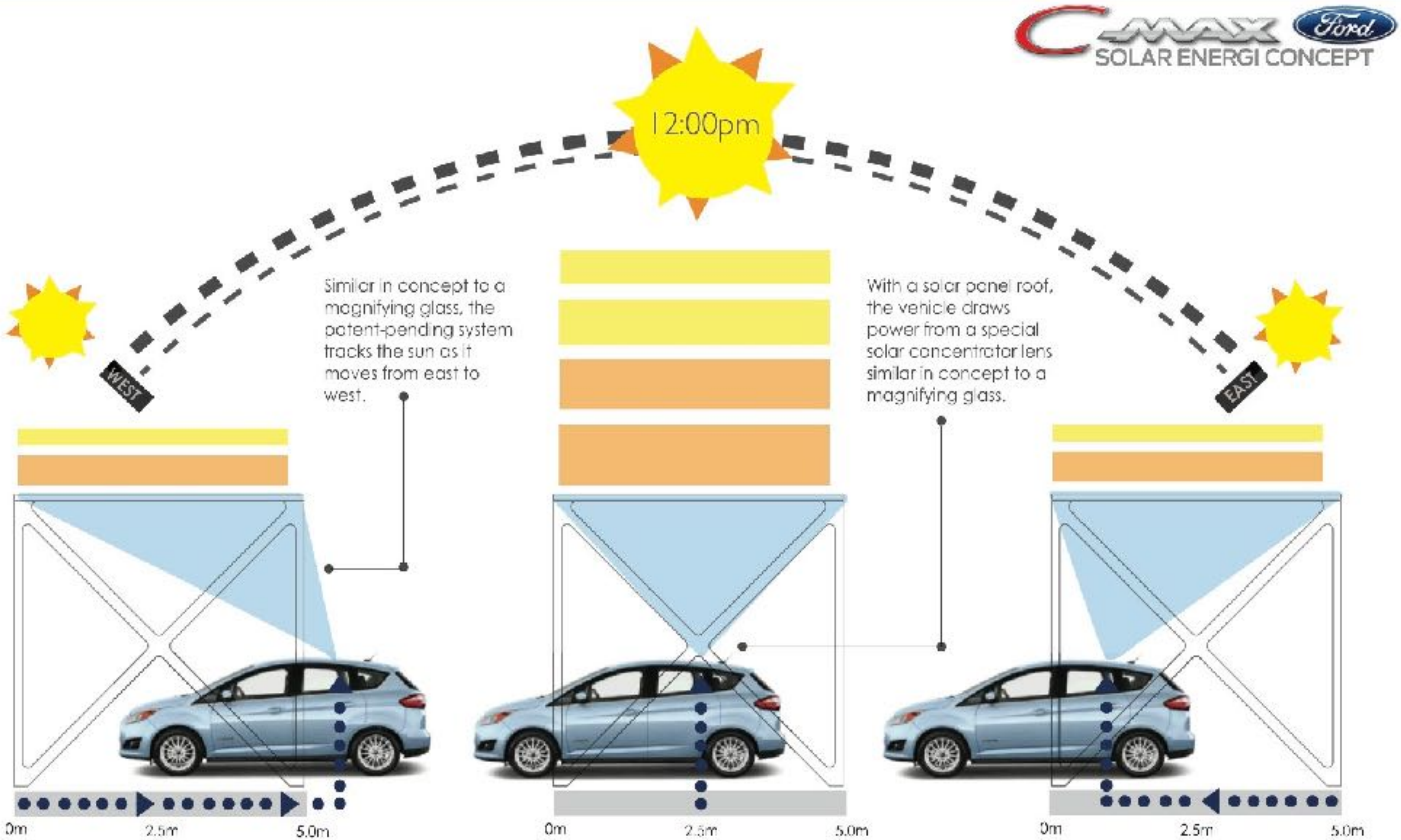
Rawlemon
RIP 2017?



Ford CMAX Solar Energi “Concept”

How it Works

The C-MAX Solar Energi optimizes the intake of solar power through a Fresnel lens concentrator by autonomously moving in the direct path of the sun's rays.



Concentrating
(sort of...)

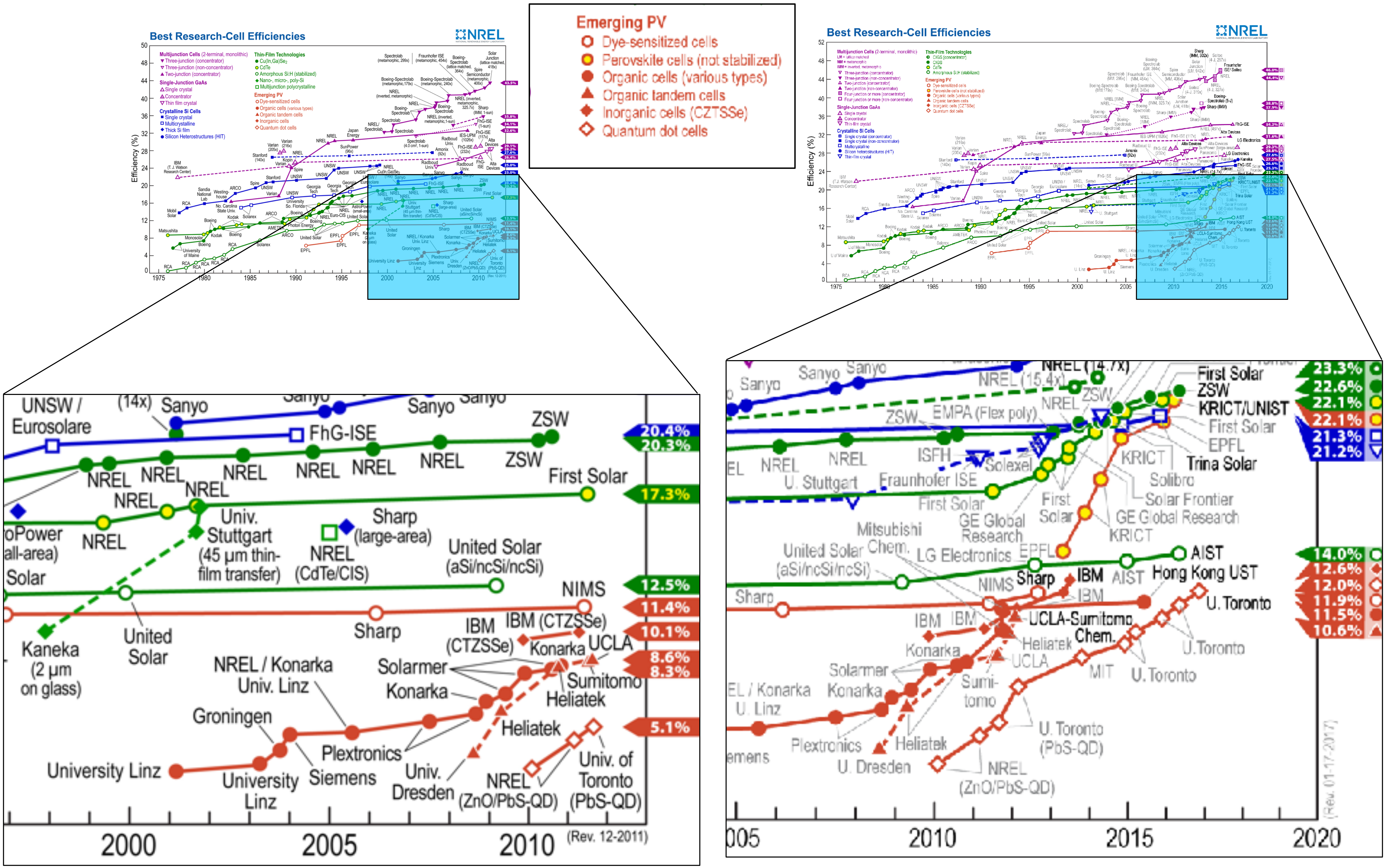
Solyndra

Figure 1 Unlike conventional p-type silicon PV cells, SolarWorld's PERC cells have rear passivation layers of amorphous silicon. These rear passivation layers not only improve light-trapping properties—by reflecting light at the cell boundary back into the cell—but also make the PERC cells inherently capable of bifaciality. Moving from a fully metallized rear electrode (on left) to one that is selectively metallized (on right) allows light to reach the back side of the bifacial cell.

SolarPro Magazine

Yingli bifacial panels

2012 2017



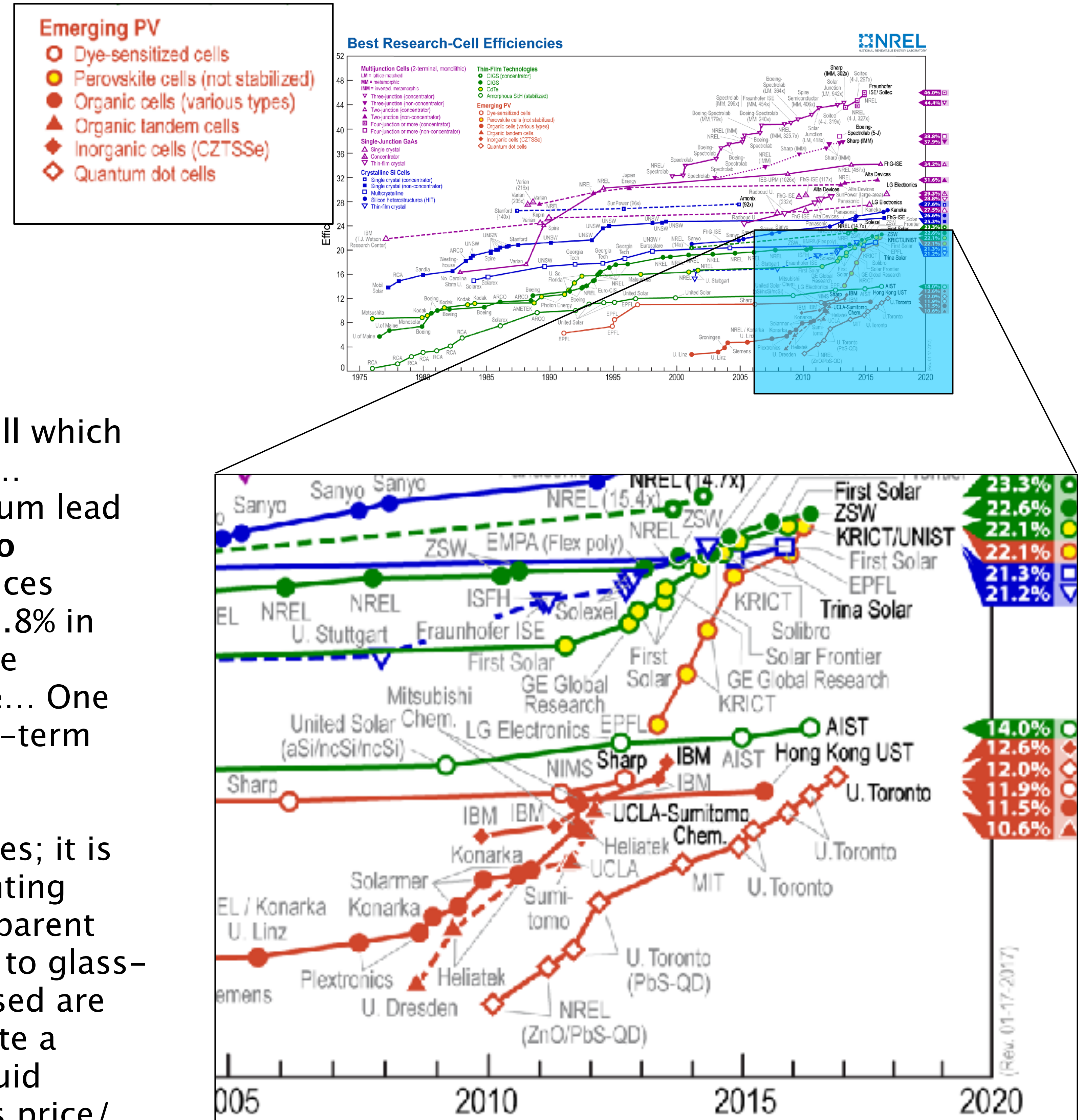
Source: DOE NREL

“**Quantum dots** (QD) are very small semiconductor particles, only several nanometres in size, so small that their optical and electronic properties differ from those of larger particles… The tunable absorption spectrum and high extinction coefficients of quantum dots make them attractive for light harvesting technologies such as photovoltaics” – Wikipedia

“A **perovskite solar** cell is a type of solar cell which includes a perovskite structured compound… Perovskite materials such as methylammonium lead halides are **cheap to produce and simple to manufacture**….Solar cell efficiencies of devices using these materials have increased from 3.8% in 2009 to 22.1% in early 2016, making this the **fastest-advancing** solar technology to date… One big challenge for PSCs is the aspect of short-term and long-term **stability**.” — Wikipedia

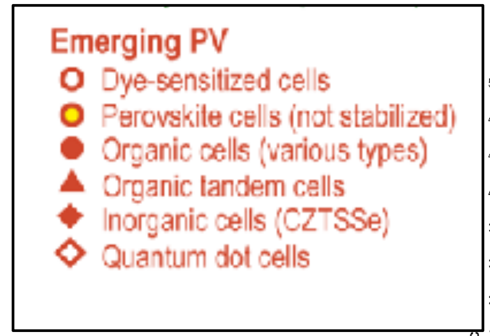
“The **DSSC** has a number of attractive features; it is **simple** to make using conventional roll-printing techniques, is semi-flexible and semi-transparent which offers a variety of uses not applicable to glass-based systems, and most of the materials used are **low-cost**… it has proven difficult to eliminate a number of expensive materials…and the liquid electrolyte presents a serious challenge… its price/performance ratio should be good enough to allow them to… [achieve] grid parity. Commercial applications… were held up due to chemical stability problems.” — Wikipedia

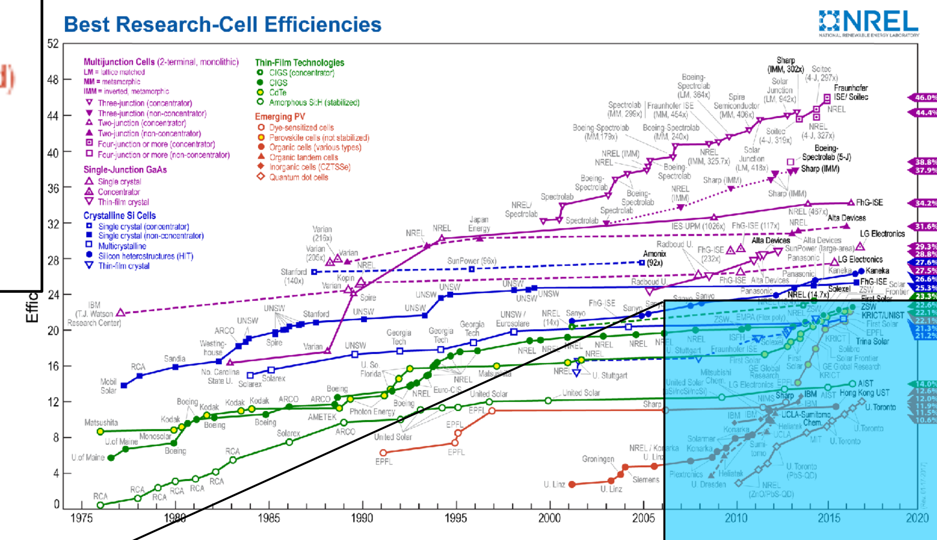
2017



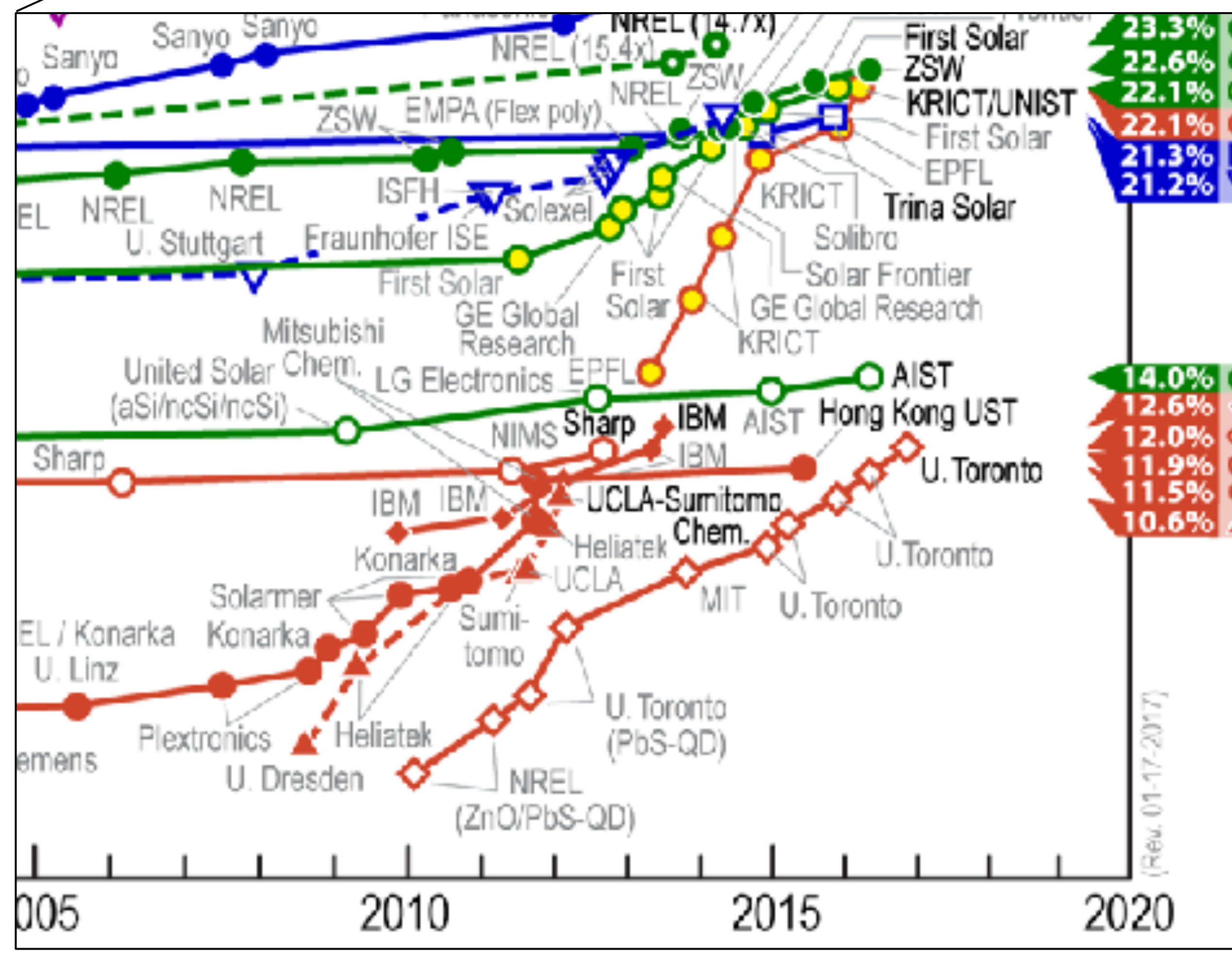
Source: DOE NREL

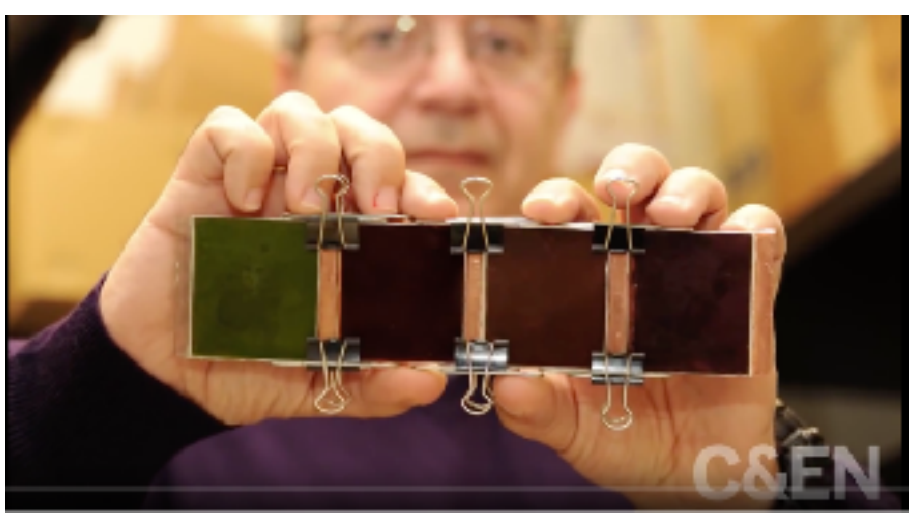
2017





“A **perovskite solar** cell is a type of solar cell which includes a perovskite structured compound… Perovskite materials such as methylammonium lead halides are **cheap to produce and simple to manufacture**….Solar cell efficiencies of devices using these materials have increased from 3.8% in 2009 to 22.1% in early 2016, making this the **fastest-advancing** solar technology to date… One big challenge for PSCs is the aspect of short-term and long-term **stability**.” — Wikipedia



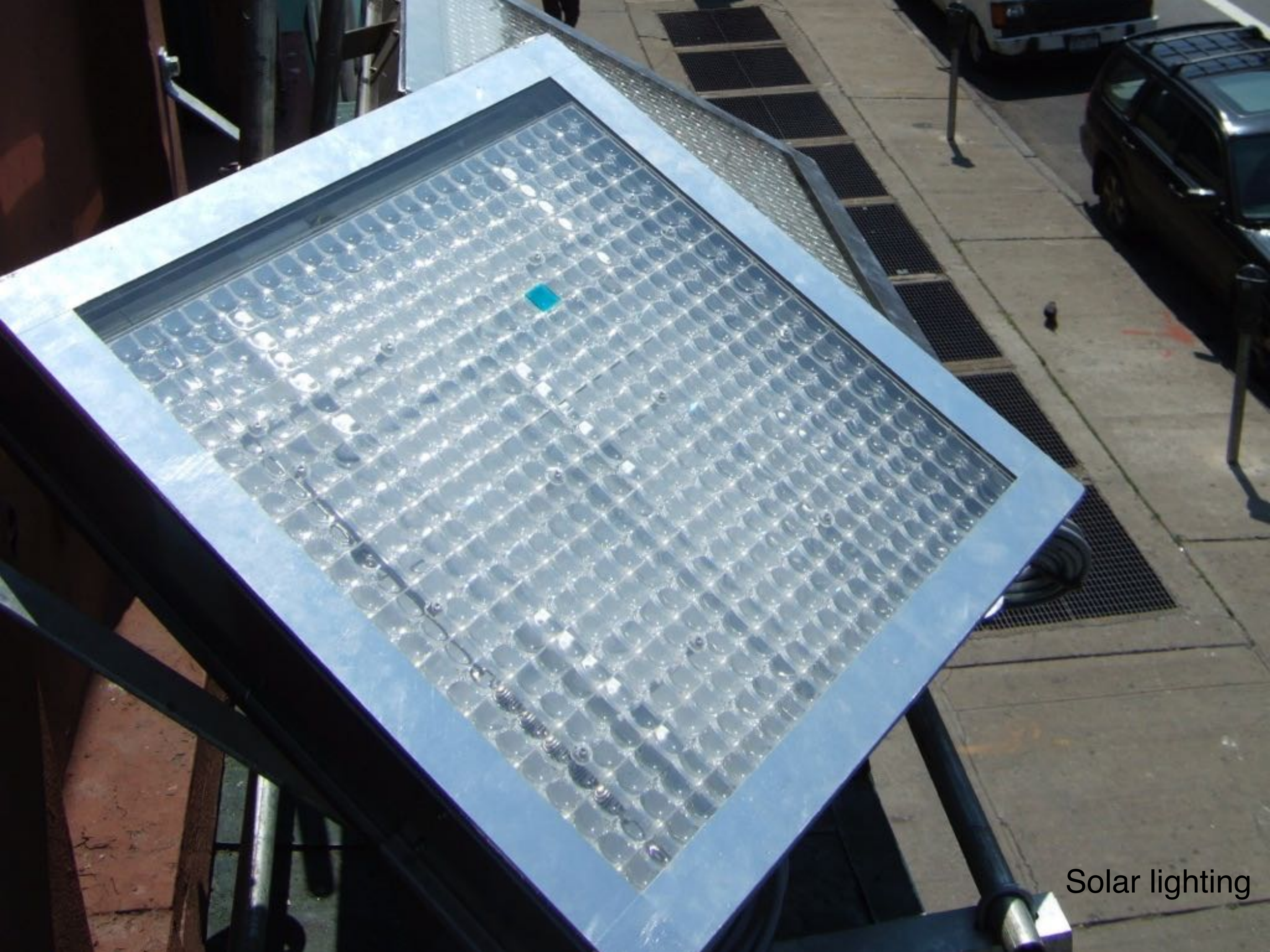


Source: DOE NREL

https://www.youtube.com/watch?v=oQ2bz6jlbz0

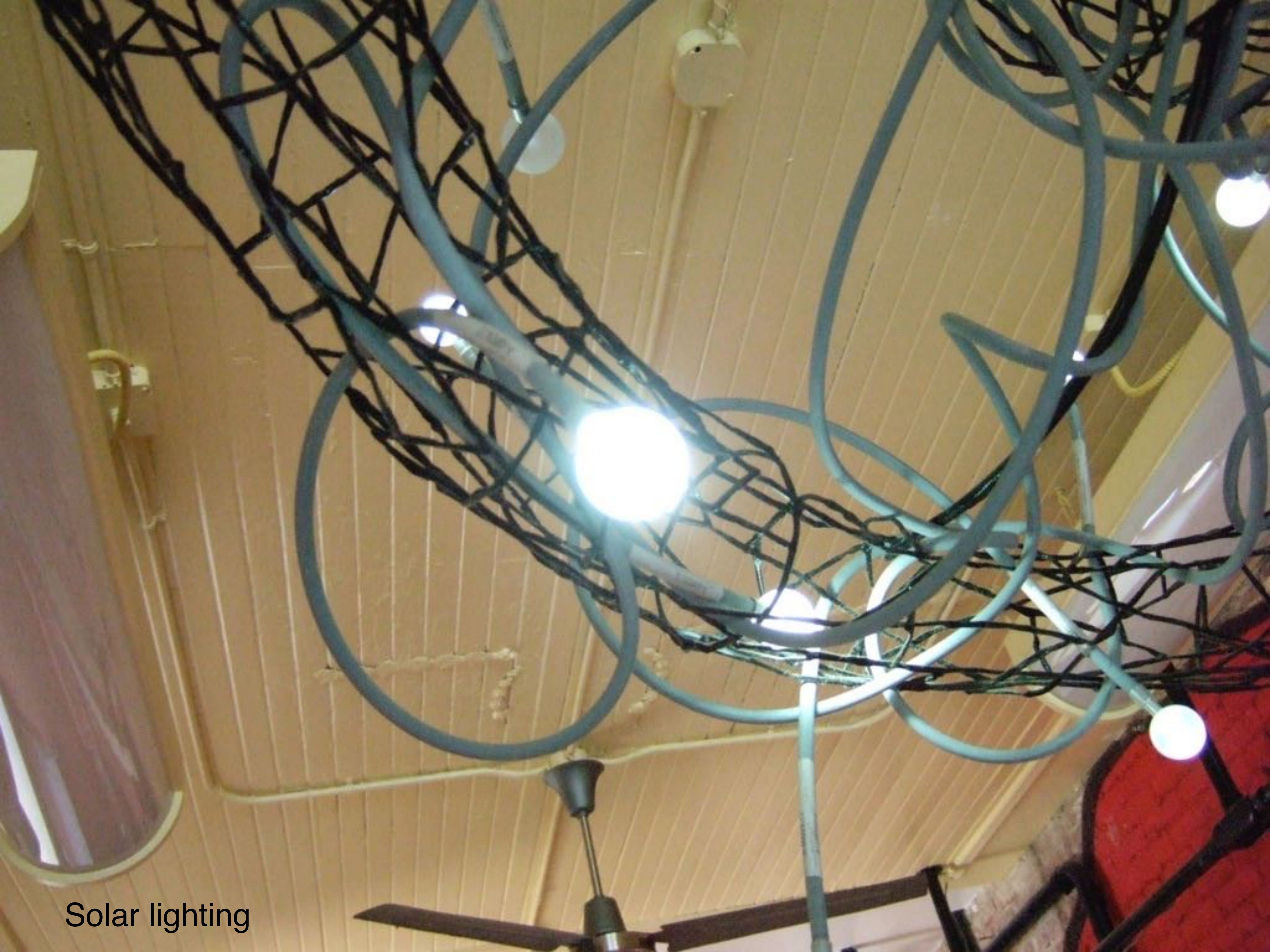
Balance of system
Tracking methods
Concentrating systems
Solar lighting
Solar thermal

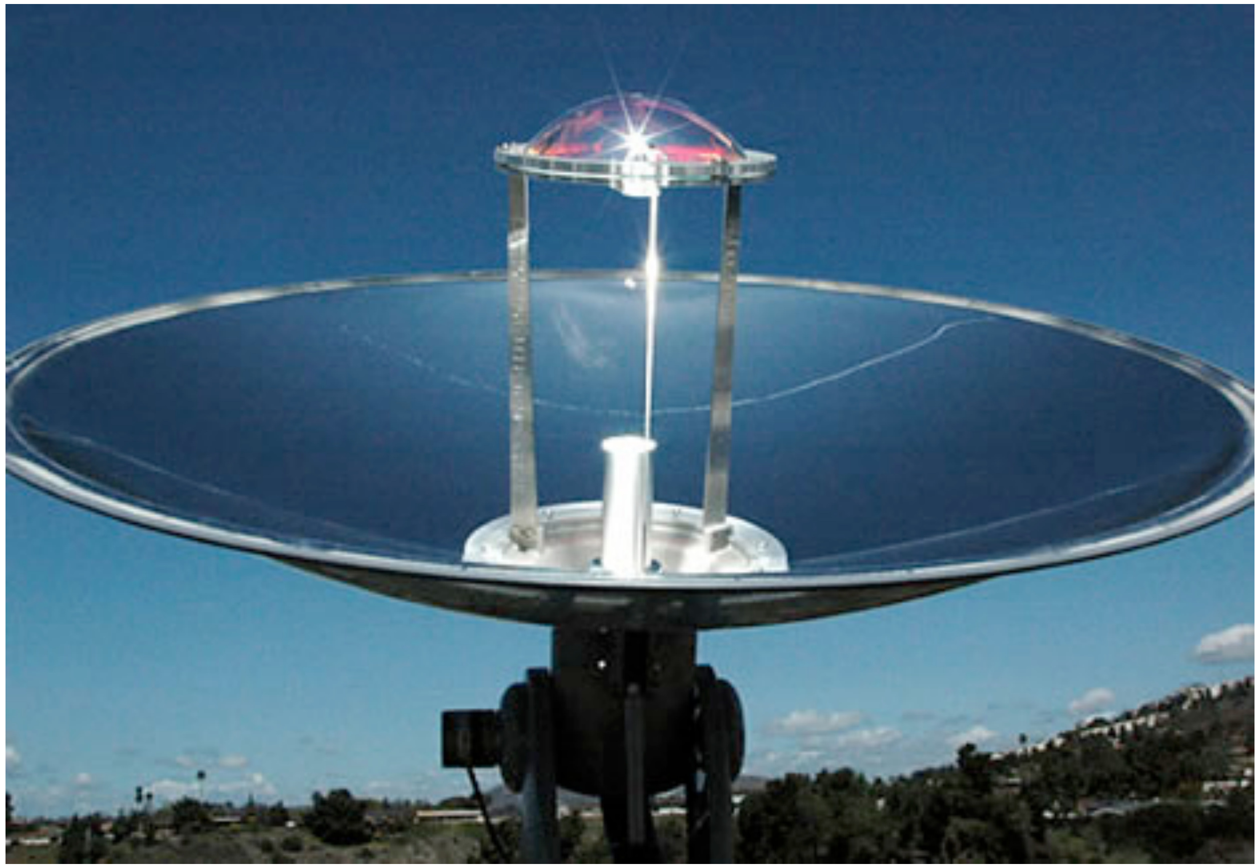
also:
Kardashev scale
Space based solar power
Dyson swarms



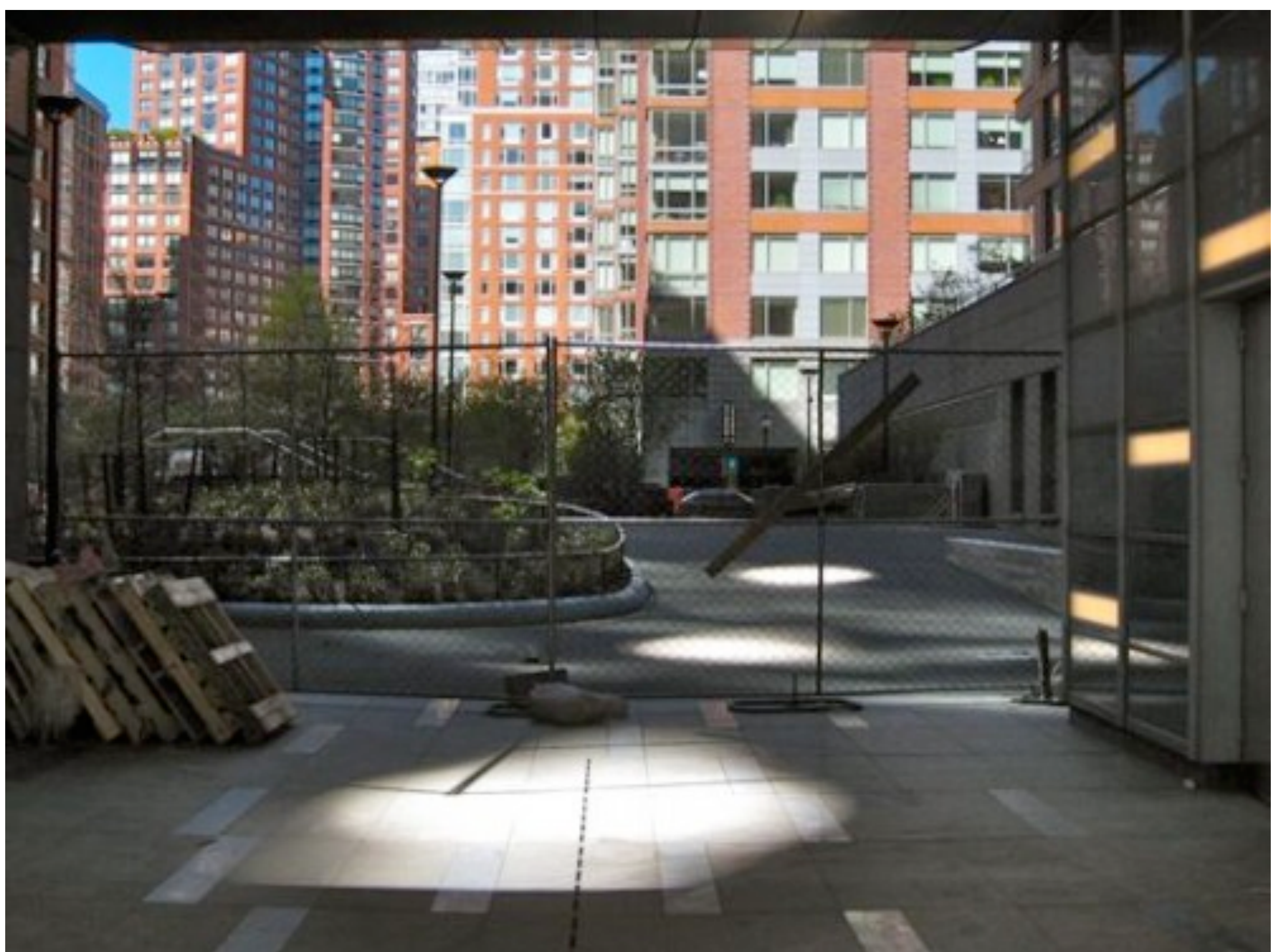
Solar lighting

Solar lighting


Solar lighting



Solar lighting



Solar lighting: Teardrop park heliostats

Carpenter Norris Consulting Inc.




Balance of system
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Solar lighting
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also:
Kardashev scale
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Dyson swarms


Solar thermal


Solar thermal


Solar thermal


Solar thermal
Sunnergy

Solar thermal

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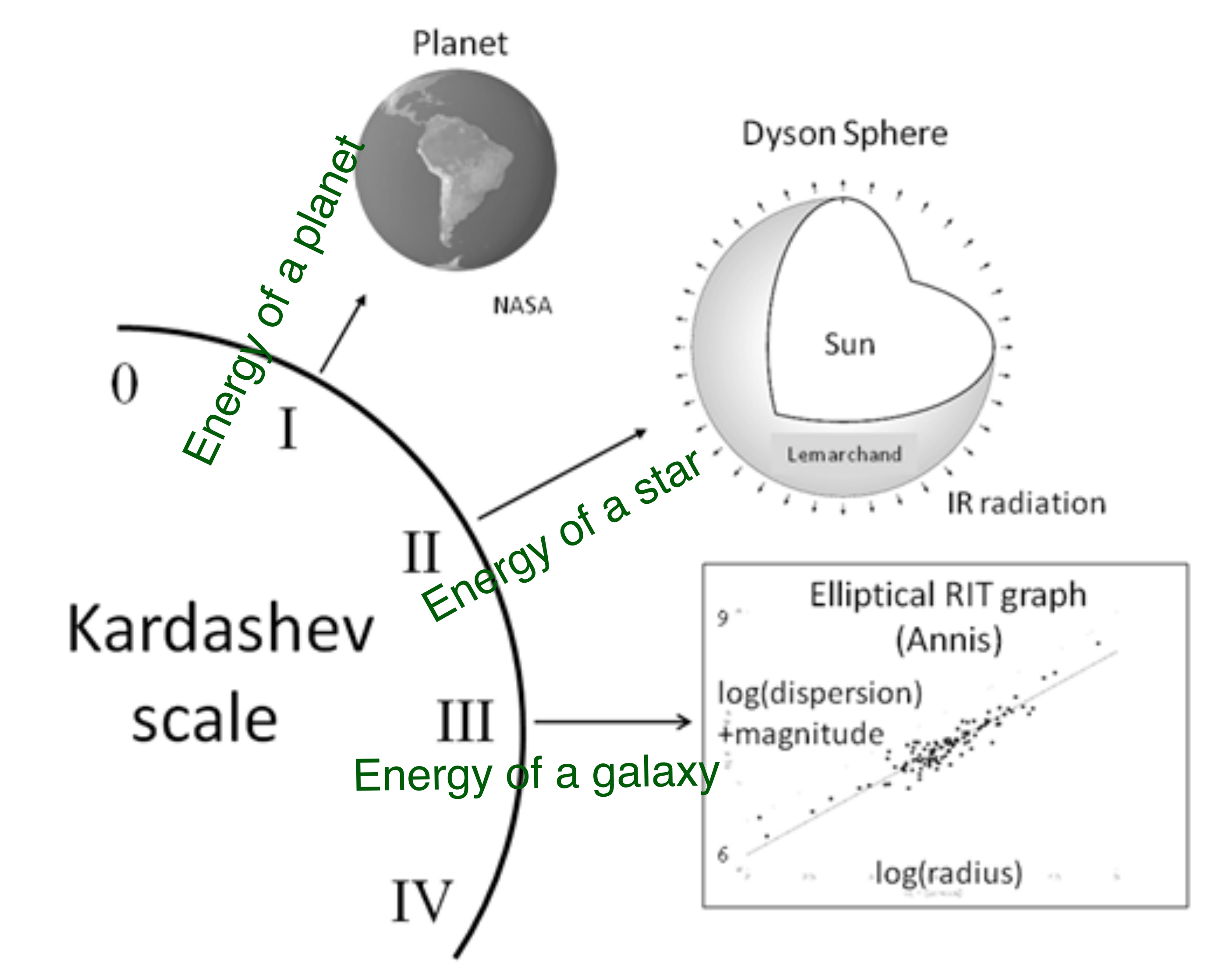
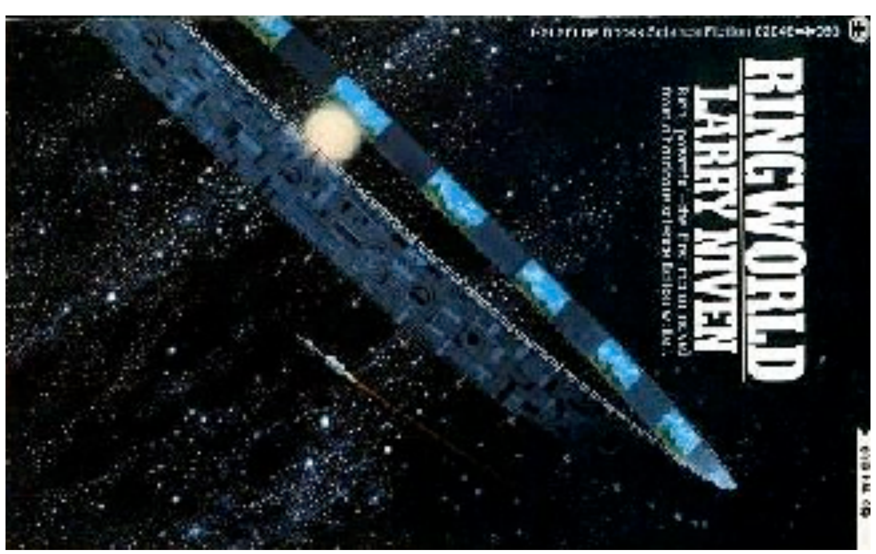
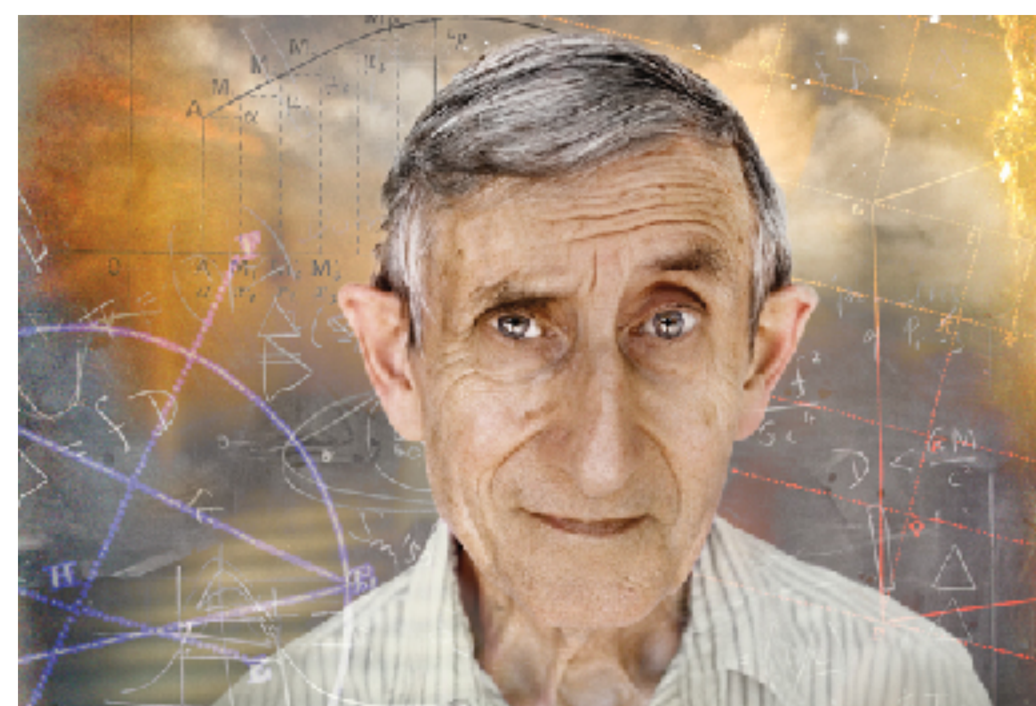


Nikolai Kardashev





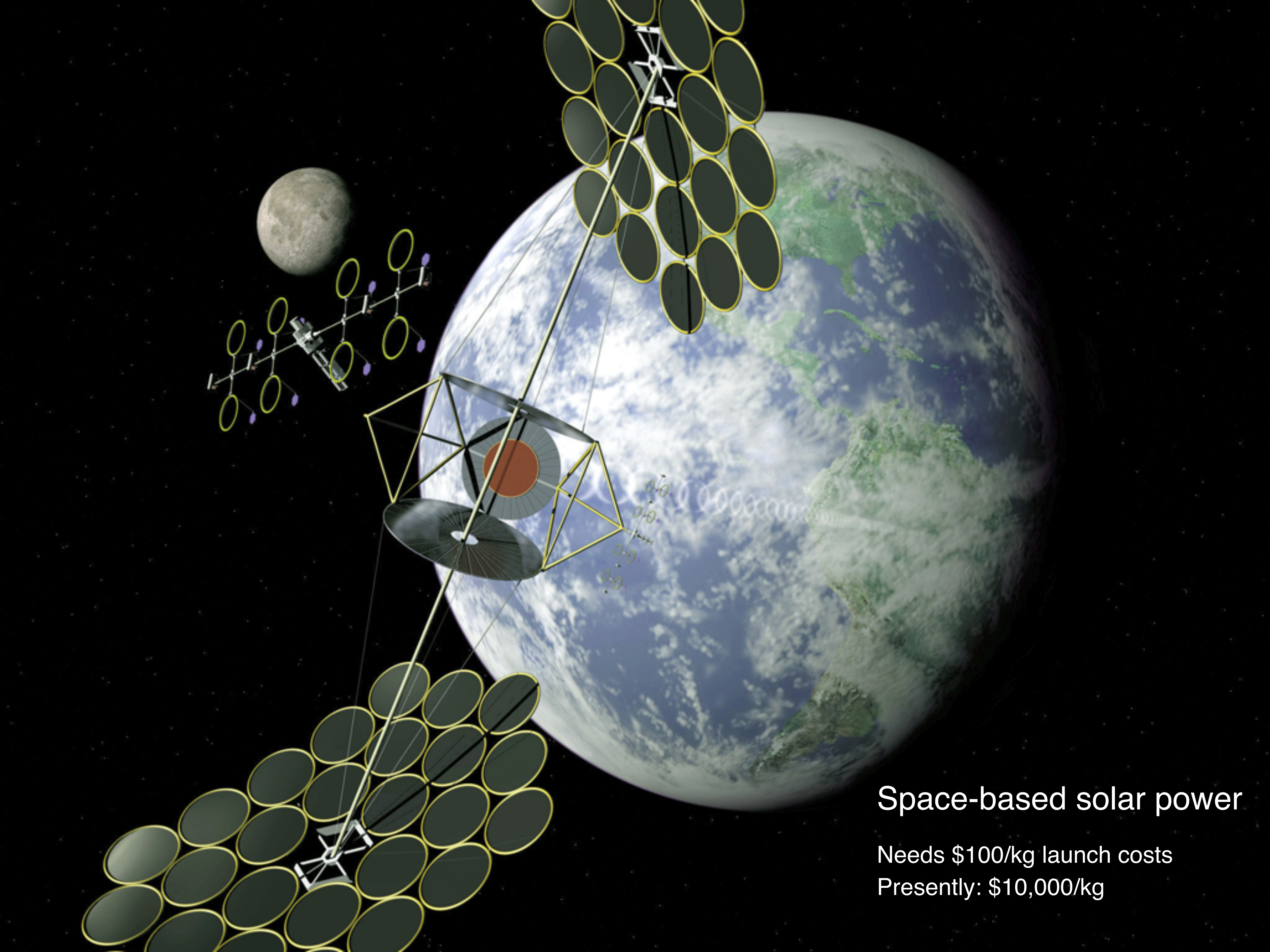
Freeman Dyson

Kardashev scale, Dyson swarms (or rings or spheres)

“Tabby’s Star” KIC 8462852

Probably *not* a Dyson Sphere… :(

https://creationexotheology.files.wordpress.com/2017/01/wp-1484580548367.jpg



Space-based solar power

Needs $100/kg launch costs
Presently: $10,000/kg

CAPABILITIES & SERVICES

SpaceX offers open and fixed pricing for its launch services. Modest discounts are available for contractually committed, multi-launch purchases. Prices shown below are paid in full standard launch prices for 2013. SpaceX can also offer crew transportation services to commercial customers seeking to transport astronauts to alternate LEO destinations. Please contact sales@spacex.com for details.

FALCON 9 →

FALCON HEAVY ›

PRIVATE CREW PROGRAM →

Space-based solar power

Needs $100/kg launch costs

$2200/kg
2018 estimate

PRICE	FALCON 9	FALCON HEAVY	
PAID IN FULL STANDARD LAUNCH PRICES (2013)	$56.5M	$77.1M Up to 6.4 ton to GTO	$135M Greater than 6.4 ton to GTO

PERFORMANCE	FALCON 9 INCLINATION	FALCON 9 PERFORMANCE	FALCON HEAVY INCLINATION	FALCON HEAVY PERFORMANCE
LOW EARTH ORBIT (LEO)	28.5°	13,150 kg 28,991 lb	28.5°	53,000 kg 116,845 lb
GEOSYNCHRONOUS TRANSFER ORBIT (GTO)	27°	4,850 kg 10,692 lb	27°	21,200 kg 46,738 lb

From “**Do the Math**”

I sense that people have a tendency to think space is easy… Once in space, failures cannot be serviced. The usual mitigation strategy is redundancy, adding weight and cost. A space-based solar power system might sound very cool and futuristic, and it may seem at first blush an obvious answer to intermittency, but this comes at a big cost. Among the possibly unanticipated challenges:

- **The gain over the a good location on the ground is only a factor of 3 (2.4× in summer, 4.2× in winter at 35° latitude).**
- It’s almost as hard to get energy back to the ground as it is to get the equipment into space in the first place.
- The microwave link faces problems with transmission through the atmosphere, and also flirts with roasting ducks on the wing.
- Diffraction of the downlink beam, together with energy density limits, means that very large areas of the ground still need to be dedicated to energy collection.

- See more at: http://physics.ucsd.edu/do-the-math/2012/03/space-based-solar-power/#sthash.k4Wv6o77.dpuf