INTRODUCTION TO SOLAR: TECHNOLOGY, RESOURCES, AND POLICIES

Energy Design Conference 2018

By

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AGENDA

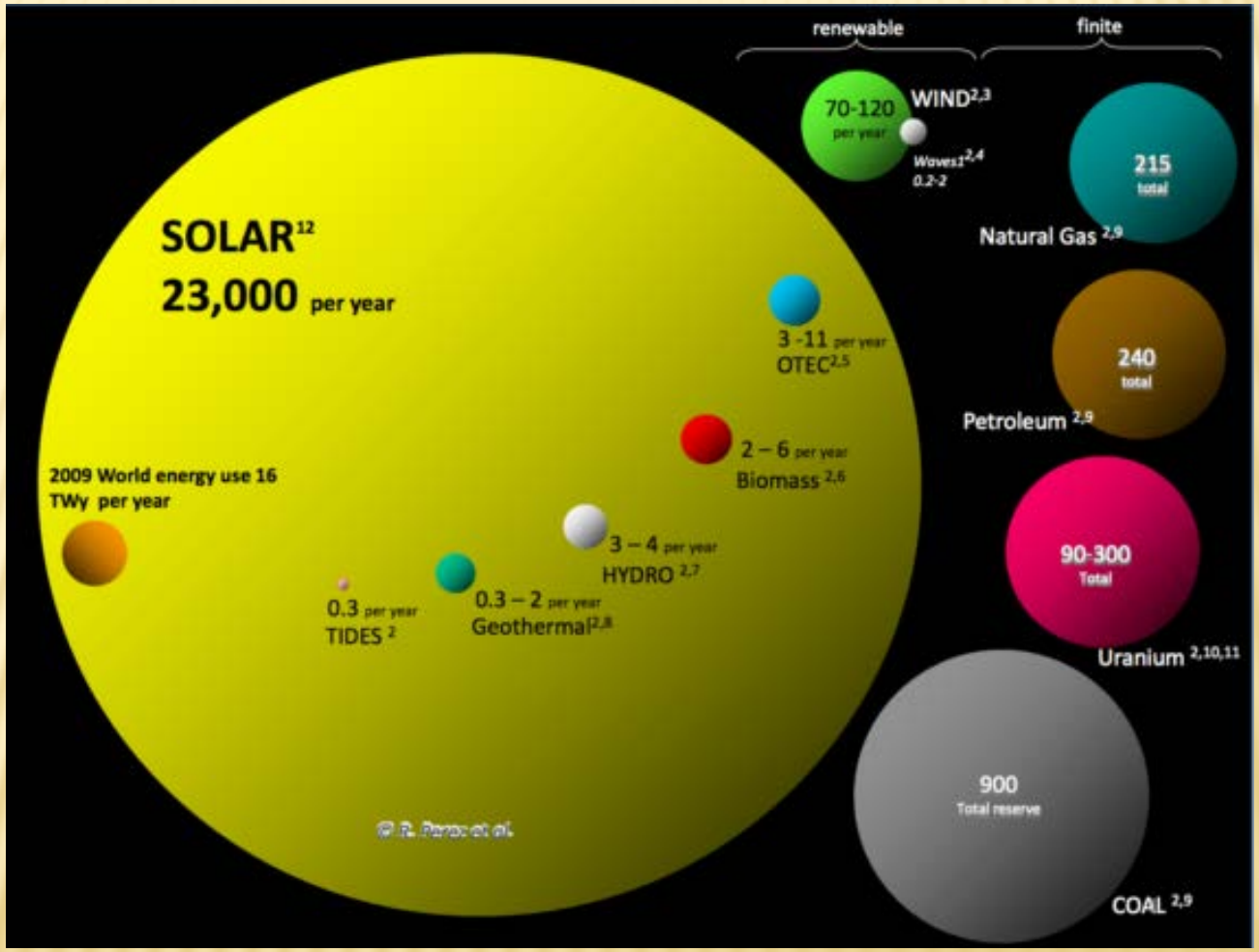
- Introduction:
- Overview: Solar Resource, Technologies, and policies
- Solar Technologies
- Market drivers and status
- Policies, Rules, and Regulations

IN ACCORDANCE WITH THE DEPARTMENT OF LABOR AND INDUSTRY'S STATUTE 326.0981, SUBD. 11,

"THIS EDUCATIONAL OFFERING IS RECOGNIZED BY THE MINNESOTA DEPARTMENT OF LABOR AND INDUSTRY AS SATISFYING **1 HOUR** OF CREDIT TOWARD **BUILDING OFFICIALS AND RESIDENTIAL CONTRACTORS** CONTINUING EDUCATION REQUIREMENTS."

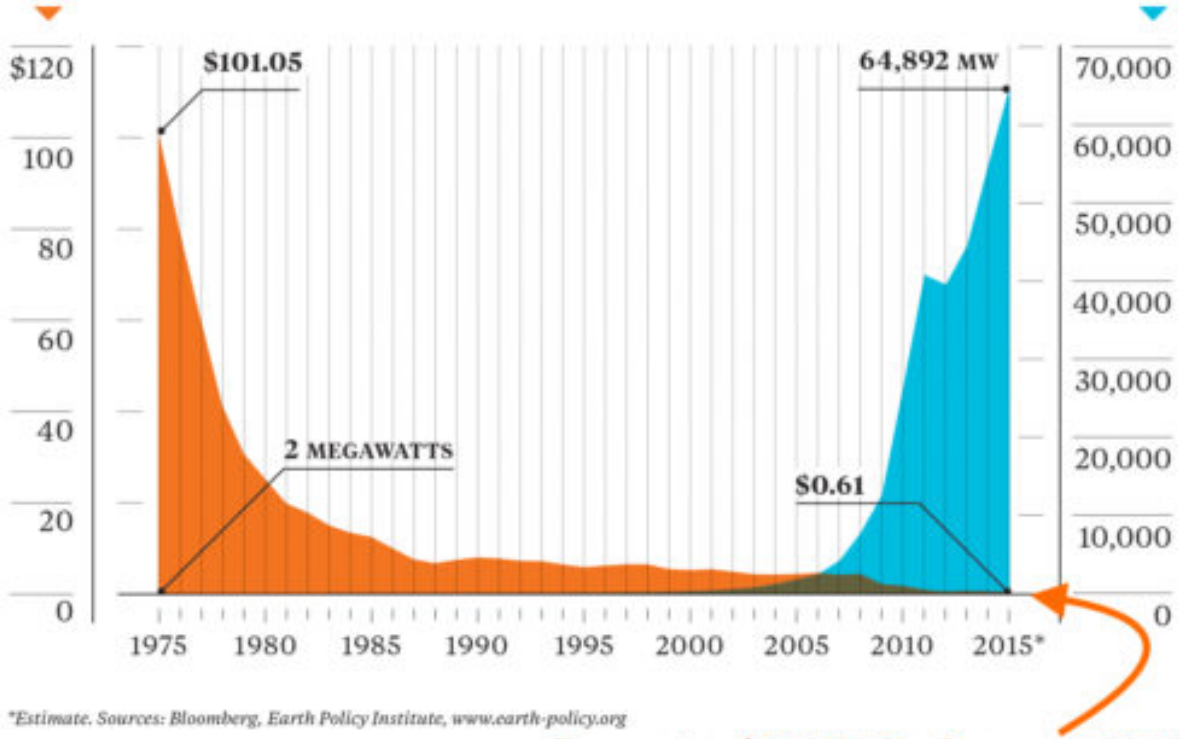
FOR ADDITIONAL CONTINUING EDUCATION APPROVALS, PLEASE SEE YOUR CREDIT TRACKING CARD.

SOLAR AS A RESOURCE



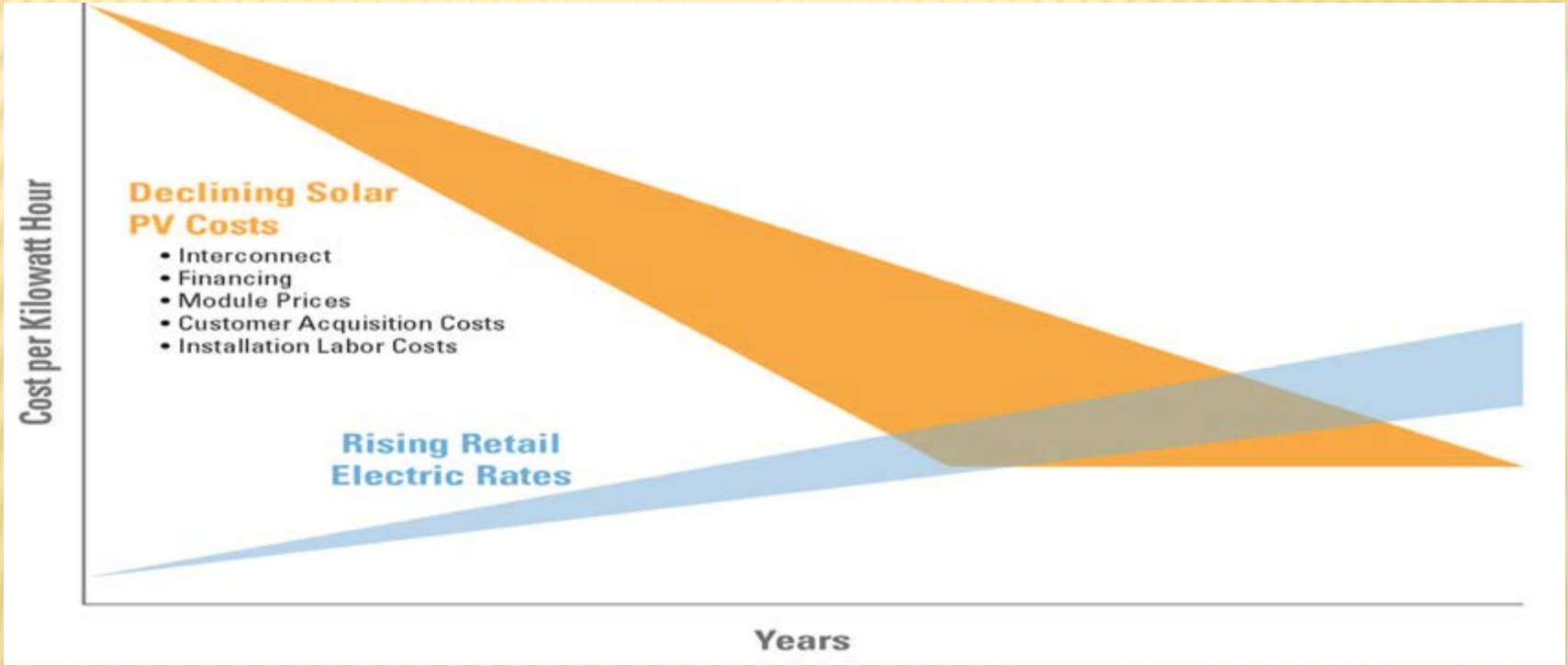
Solar on Fire

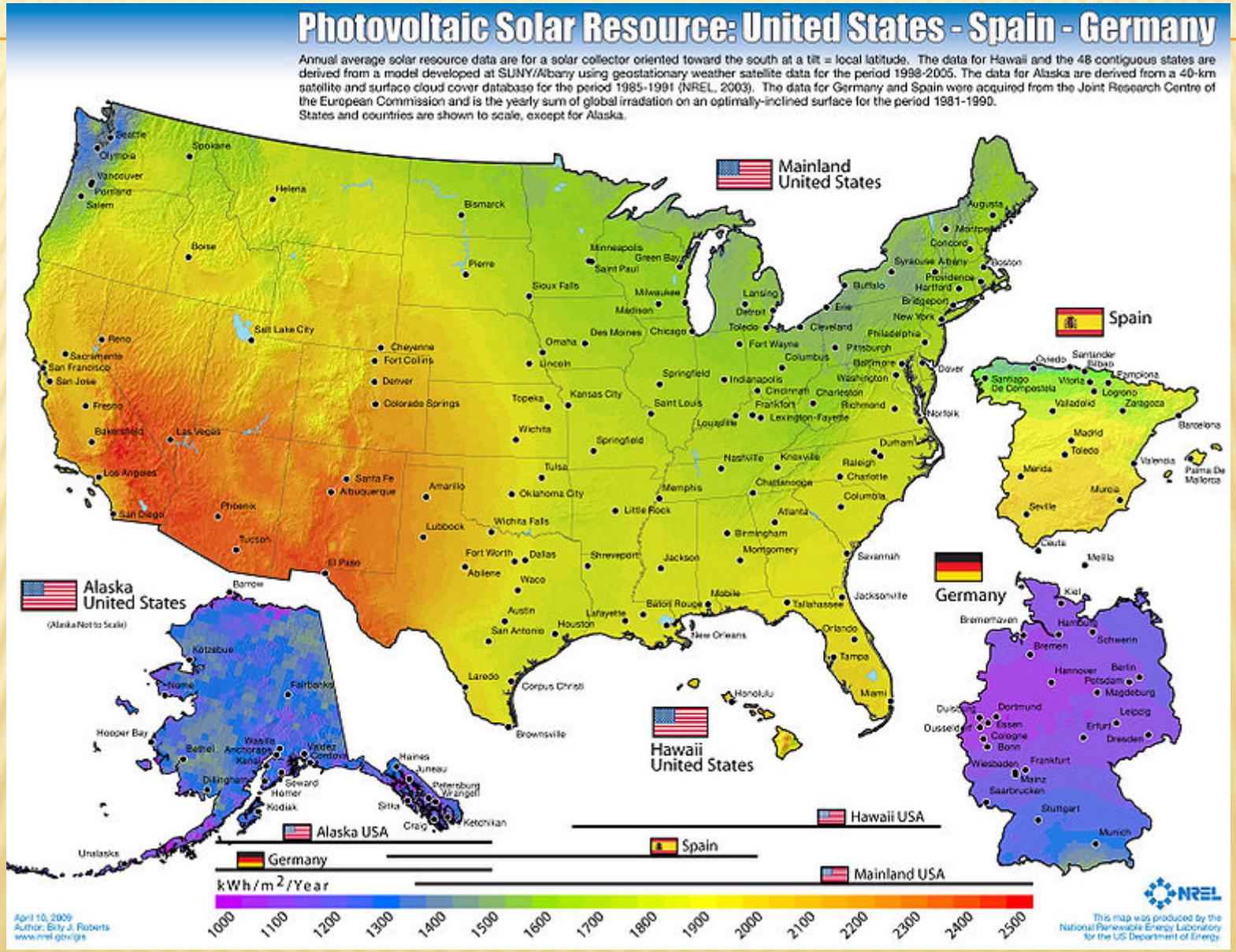
As prices have dropped, installations have skyrocketed.



COST OF SOLAR

- Historic- 1950's $300/W, 1970's $50/w, 1990's $10/w, today <$1/w

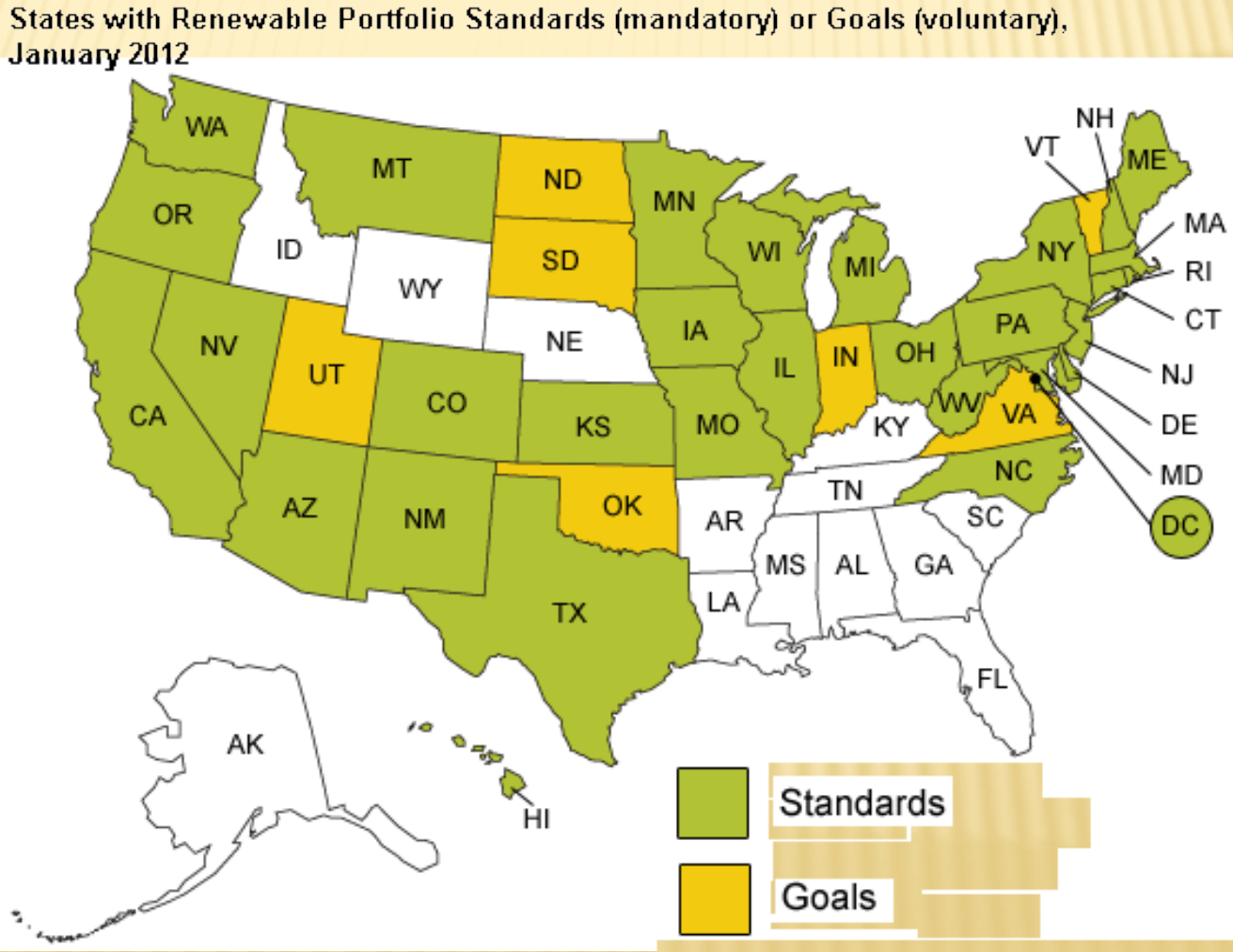



Photovoltaic Solar Resource: United States - Spain - Germany
Annual average solar resource data are for a solar collector oriented toward the south at a tilt = local latitude. The data for Hawaii and the 48 contiguous states are derived from a model developed at SUNY/Albany using geostationary weather satellite data for the period 1998-2005. The data for Alaska are derived from a 40-km satellite and surface cloud cover database for the period 1985-1991 (NREL, 2003). The data for Germany and Spain were acquired from the Joint Research Centre of the European Commission and is the yearly sum of global irradiation on an optimally-inclined surface for the period 1981-1990.
States and countries are shown to scale, except for Alaska.
Mainland United States
Spain
Alaska United States
(Alaska Not to Scale)
Germany
Hawaii United States
Hawaii USA
Alaska USA
Spain
Germany
Mainland USA
kWh/m2/Year
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
April 10, 2009
Author: Billy J. Roberts
www.nrel.gov/gis
NREL
This map was produced by the National Renewable Energy Laboratory for the US Department of Energy

POLICIES DRIVING SOLAR

- Global:
  - Germany: EnergieWende
  - China: 5 Year plans
  - USA: state level RPSs
  - Others
- Public Utilities Regulatory Policies Act 1978
- Net Metering

STATES WITH MANDATES



MINNESOTA RENEWABLE ENERGY

- Next Generation Energy Act
  - Passed in 2007 (§216C.05)
  - 25% by 2025
  - Accomplished or on target
- Solar Energy Standard

2013 Minnesota Solar Legislation

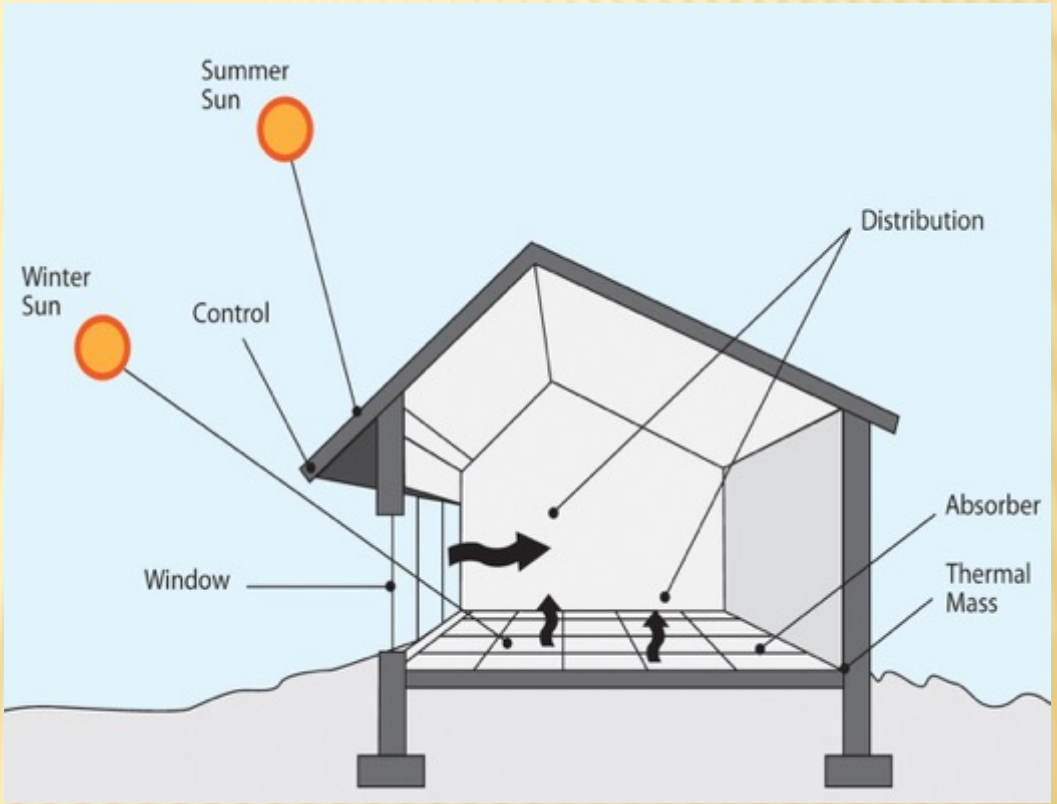
Renewable Energy Standard (RES)	**Unchanged**
Solar Energy Standard (SES)	**1.5% of Retail Sales by 2020** *(excludes mining & paper industry)*
Net Meter	**1 MW Limit** *(not to exceed 120% of usage)*
Solar Value Rate	**Value of Solar (VOS)** *(Optional for IOU's)*
Community Solar Gardens	**Xcel Required, Other IOU's Optional**
Made in MN Subsidy	**5% of CIP$**

TECHNOLOGY

- Passive
  - Heating, cooling, Lighting
- Heating and Cooling
  - Systems and collector types
  - Hot water
  - Hot air
- Electricity
  - Thermal
  - Photovoltaic (PV)

PASSIVE

- Using design to control energy from the sun entering the building
- Orientation, overhangs, and positioning of windows



SOLAR THERMAL- HOT WATER

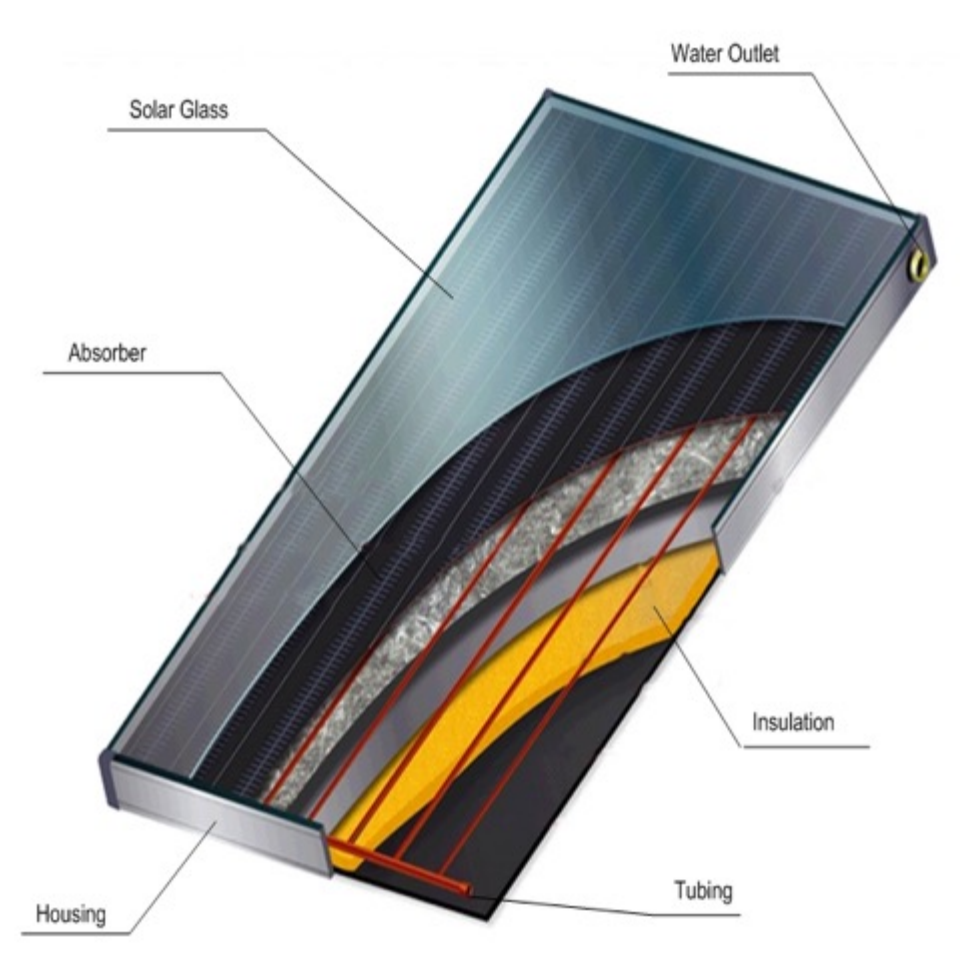
- Design types
  - Batch
  - Pressurized
  - Drain back
- System components
  - Collectors
  - Pumps
  - Pipes
  - Storage tanks
  - Controls
  - Sensors

BATCH SYSTEMS

- Used in warmer climates
- Small footprint

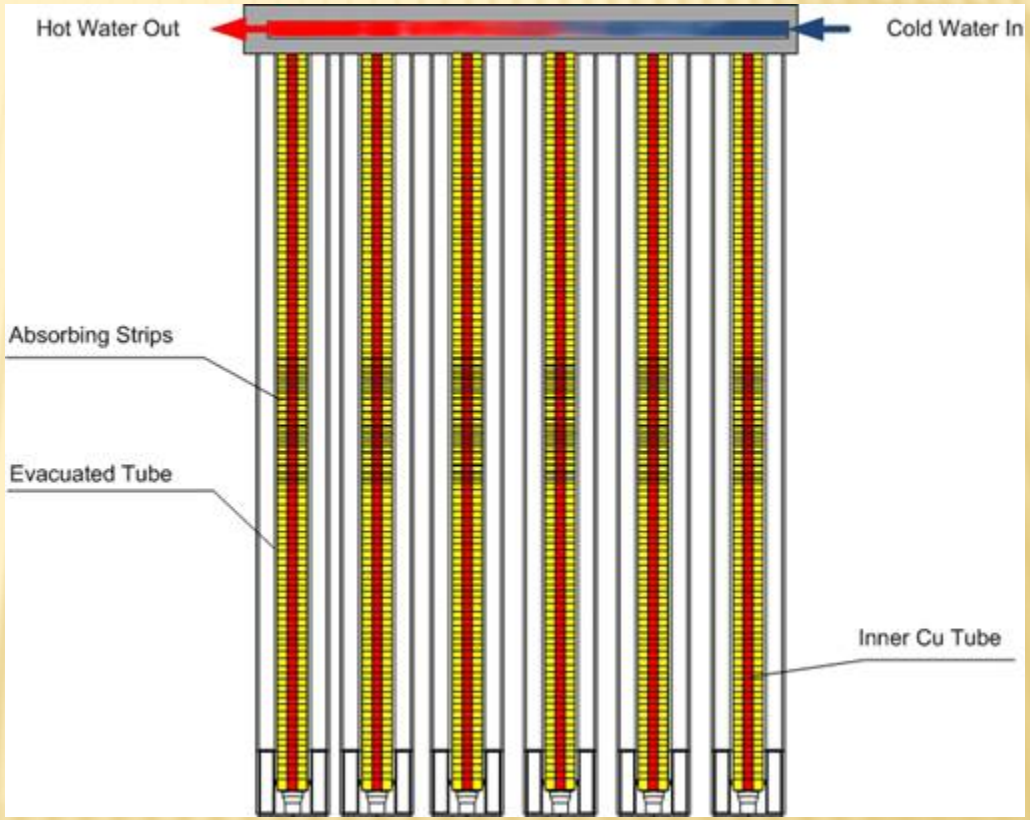
FLAT PLATE

- Flat panels
- No internal moving parts
- Collectors, tubing, insulation, glazing, frame

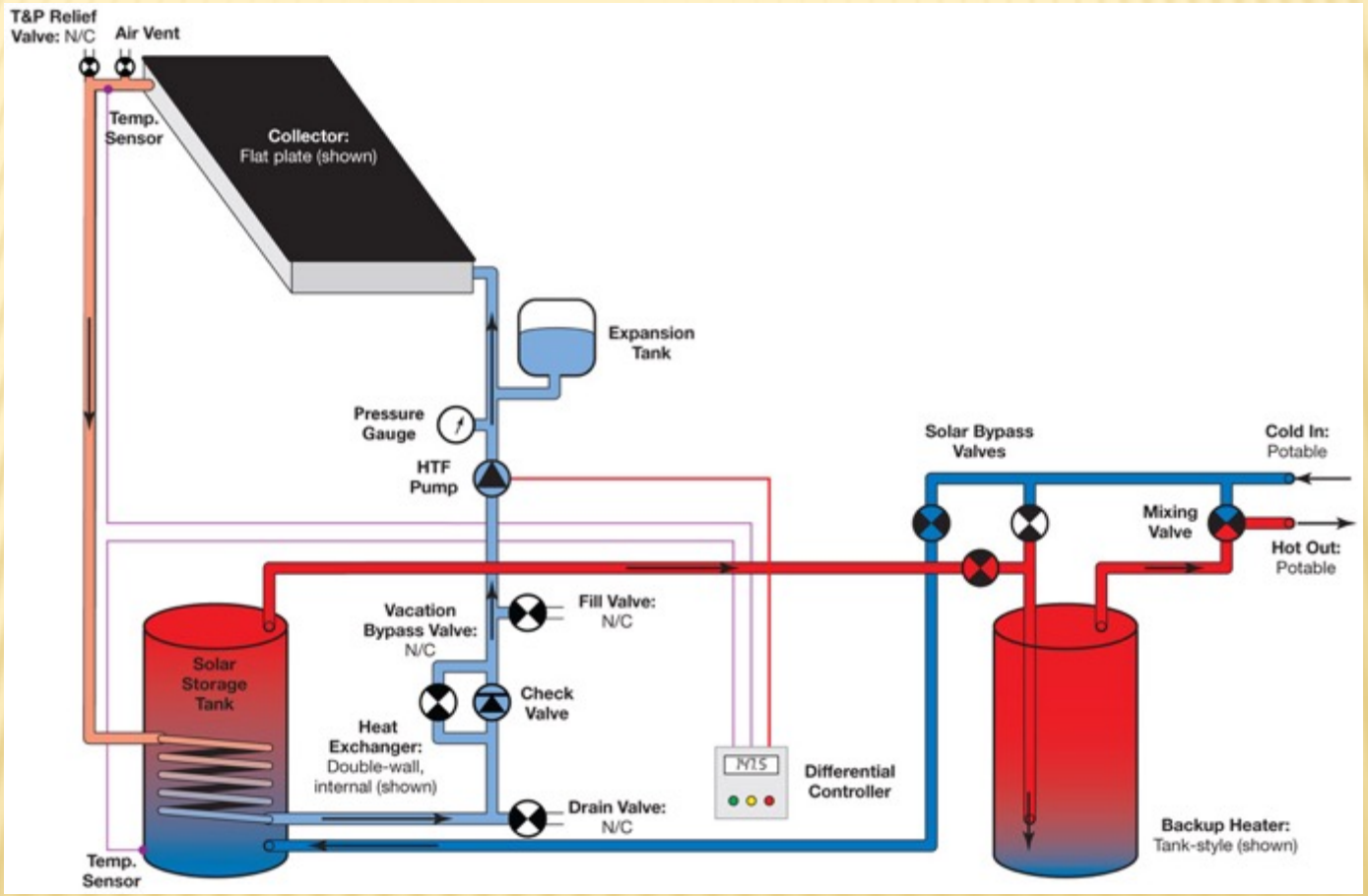


EVACUATED TUBES

- Vacuum sealed chamber around a specialized metal collector
- Top manifold to transfer heat to coolant loop
- Effective in very cold conditions
- Vacuum is key



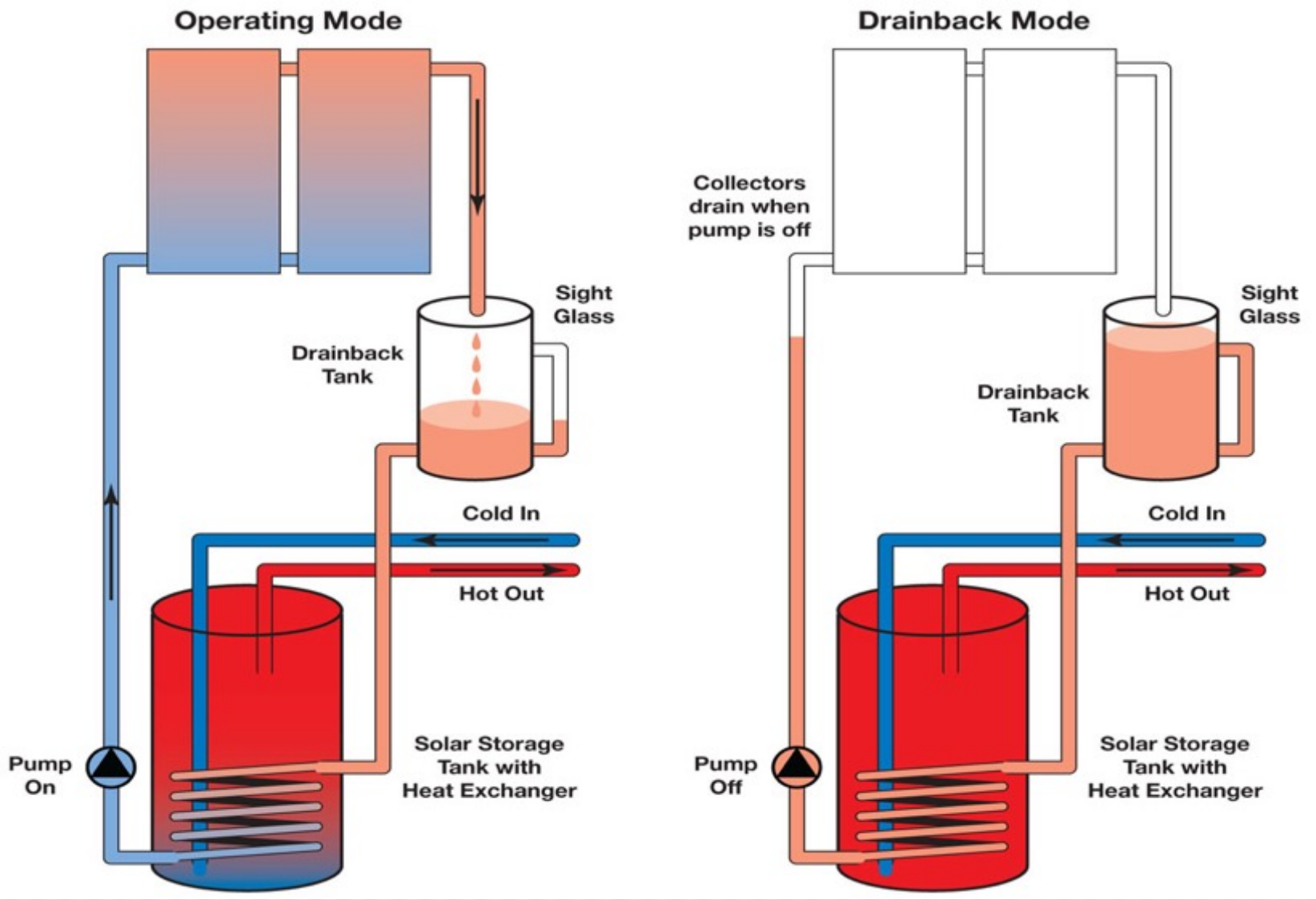
PRESSURIZED LOOP SYSTEM



PRESSURIZED LOOP SYSTEM

- Antifreeze solution for absorbing heat, and to avoid freezing
- Fluid is always in the full loop
- Requires pressure relief valves
- Must not stagnate when heat is present

DRAIN BACK SYSTEM



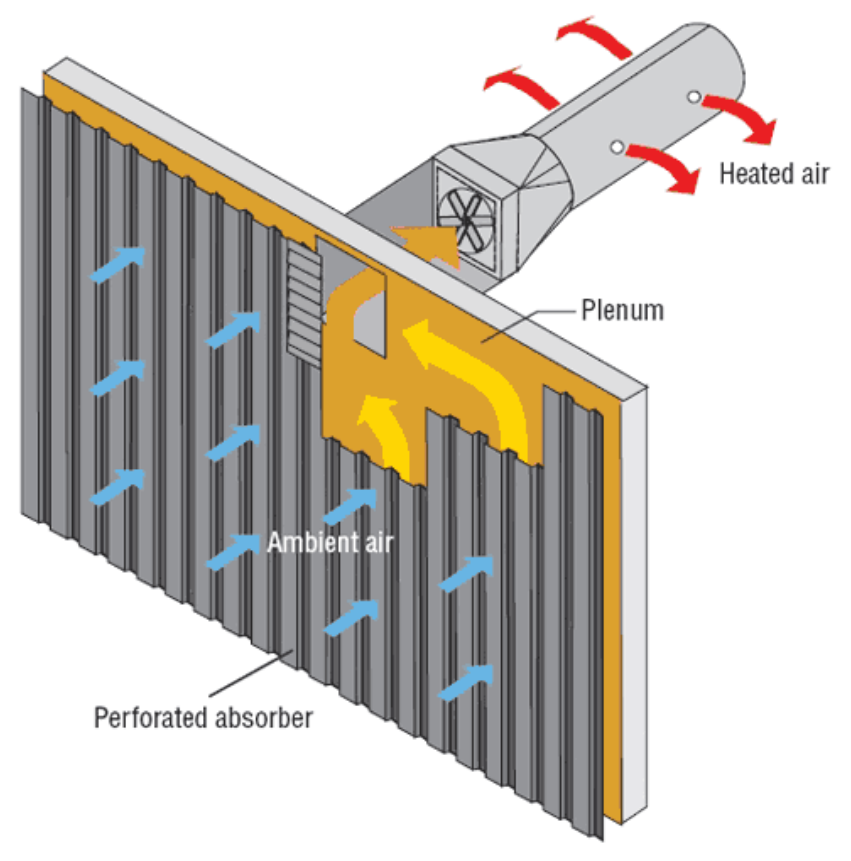
DRAIN BACK SYSTEM

- Allows fluid to drain back into a holding tank when there is no call for heat
- Differential controller activates system pumps when the conditions are correct
- Avoids overheating of fluids in system loop, avoids freeze up condition
- Less parts in these systems than pressurized loop

SOLAR THERMAL- HOT AIR

- Space heating
- Transpired air- pre conditioning

SOLAR WALLS- TRANSPIRED AIR



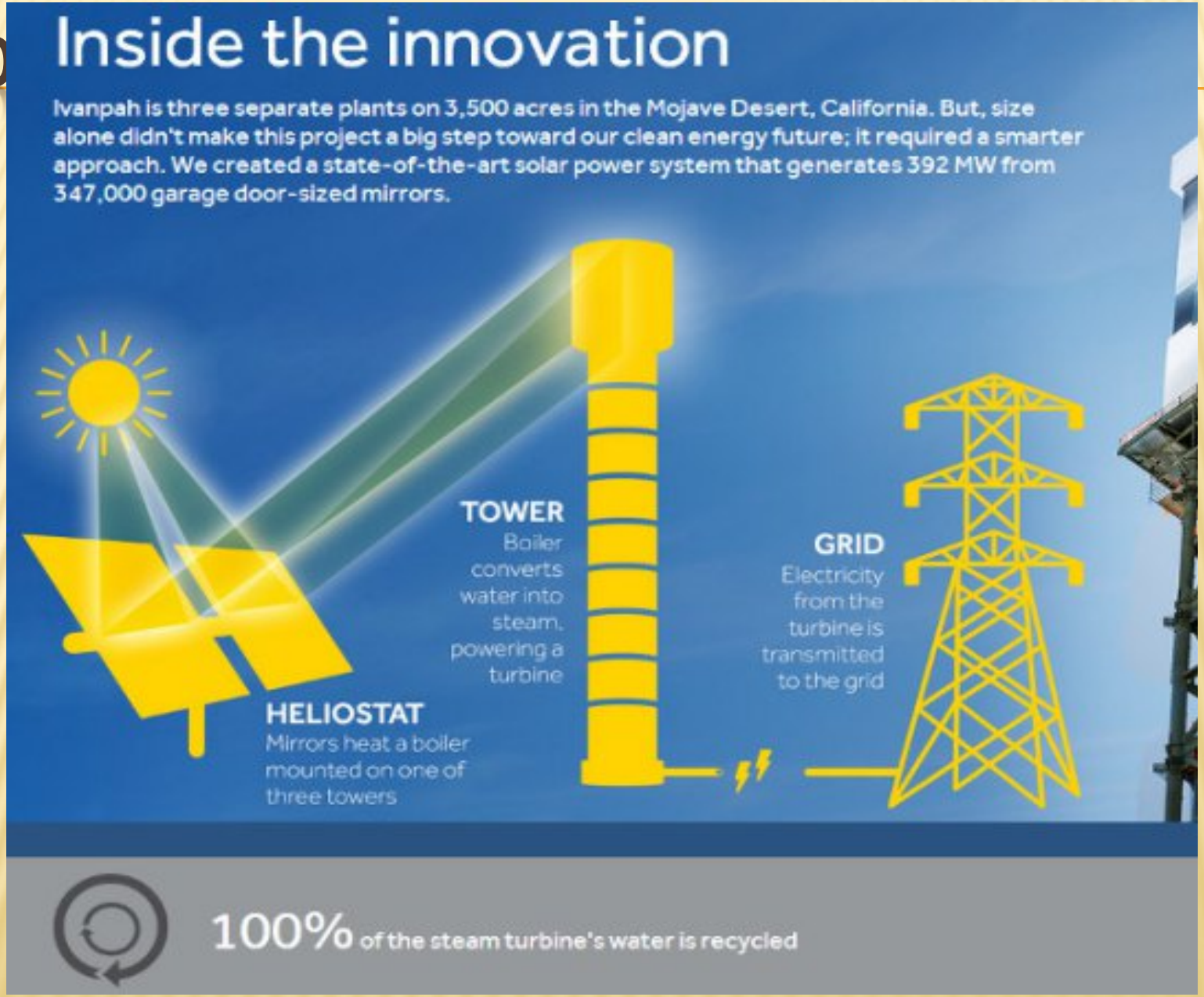
SOLAR THERMAL- GENERAL

- The current market is small
- Certifications for products through the Solar Rating and Certification Corporation (SRCC)

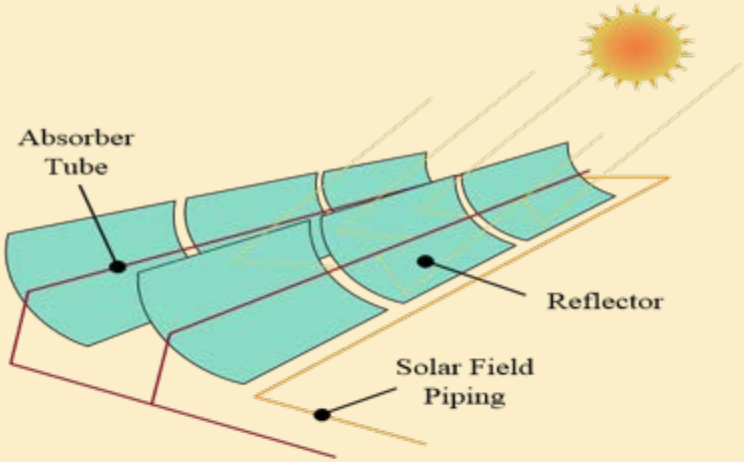
SOLAR ELECTRIC- THERMAL

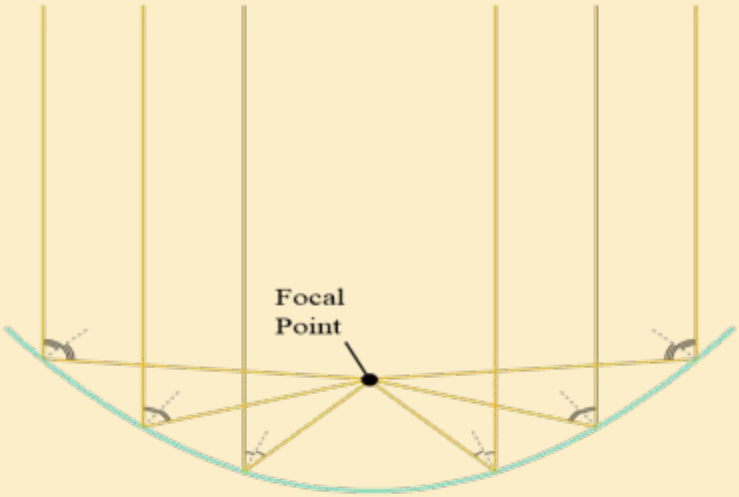
- Concentrating the sun to produce high levels of heat to create steam for power production
- Parabolic Trough and Power Towers

PO


Inside the innovation
Ivanpah is three separate plants on 3,500 acres in the Mojave Desert, California. But, size alone didn't make this project a big step toward our clean energy future; it required a smarter approach. We created a state-of-the-art solar power system that generates 392 MW from 347,000 garage door-sized mirrors.
TOWER
Boiler converts water into steam, powering a turbine
GRID
Electricity from the turbine is transmitted to the grid
HELIOSTAT
Mirrors heat a boiler mounted on one of three towers
100% of the steam turbine's water is recycled

PARABOLIC TROUGH





PHOTOVOLTAIC EFFECT

- Britannica: “Process in which two dissimilar materials in close contact produce an electrical voltage when struck by light or other radiant energy.”
- First observed by French physicist A.E. Becquerel in 1839
- First solar cells made of gold and selenium in 1884 by Charles Fritts

SOLAR ELECTRIC- PHOTOVOLTAICS (PV)

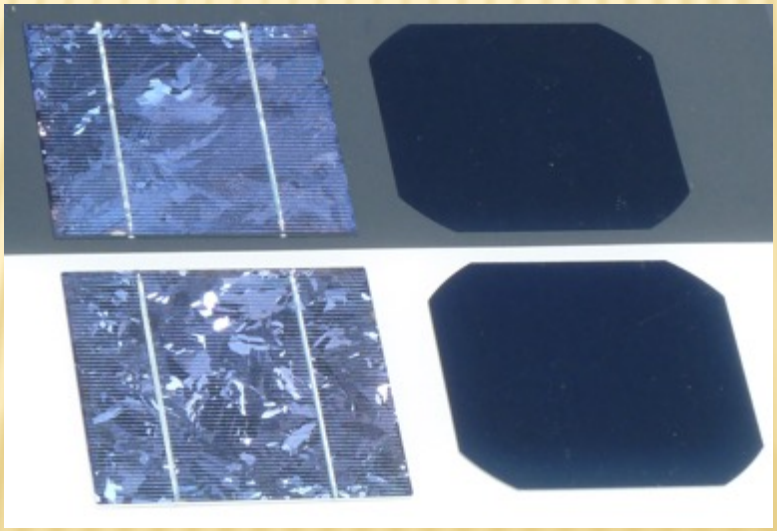
- Semiconductors exposed to light will create an electric current
- Scalable technology: from watches to utility scale system
- Dramatic improvements in technologies and costs has propelled PV into mainstream power production.
- First technology that allows homeowners to easily make their own electricity.

MATERIALS AND APPLICATIONS

- Silicon solar cells
  - Polycrystalline
  - Monocrystalline
- Thin Film
  - CIGS- Cadmium Indium Gallium Selenide
  - CdTe- Cadmium Telleride
- Others: Organic, Perovskites, Quantum Dots…

SILICON CRYSTAL CELLS

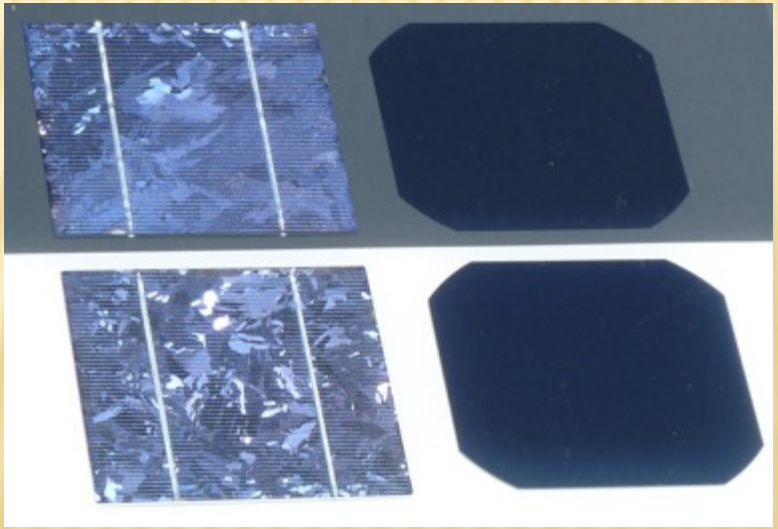
- Polycrystalline: mottled appearance due to manufacturing technique.
- Less efficient than Monocrystalline cells due to cell structure. Less costly to produce.



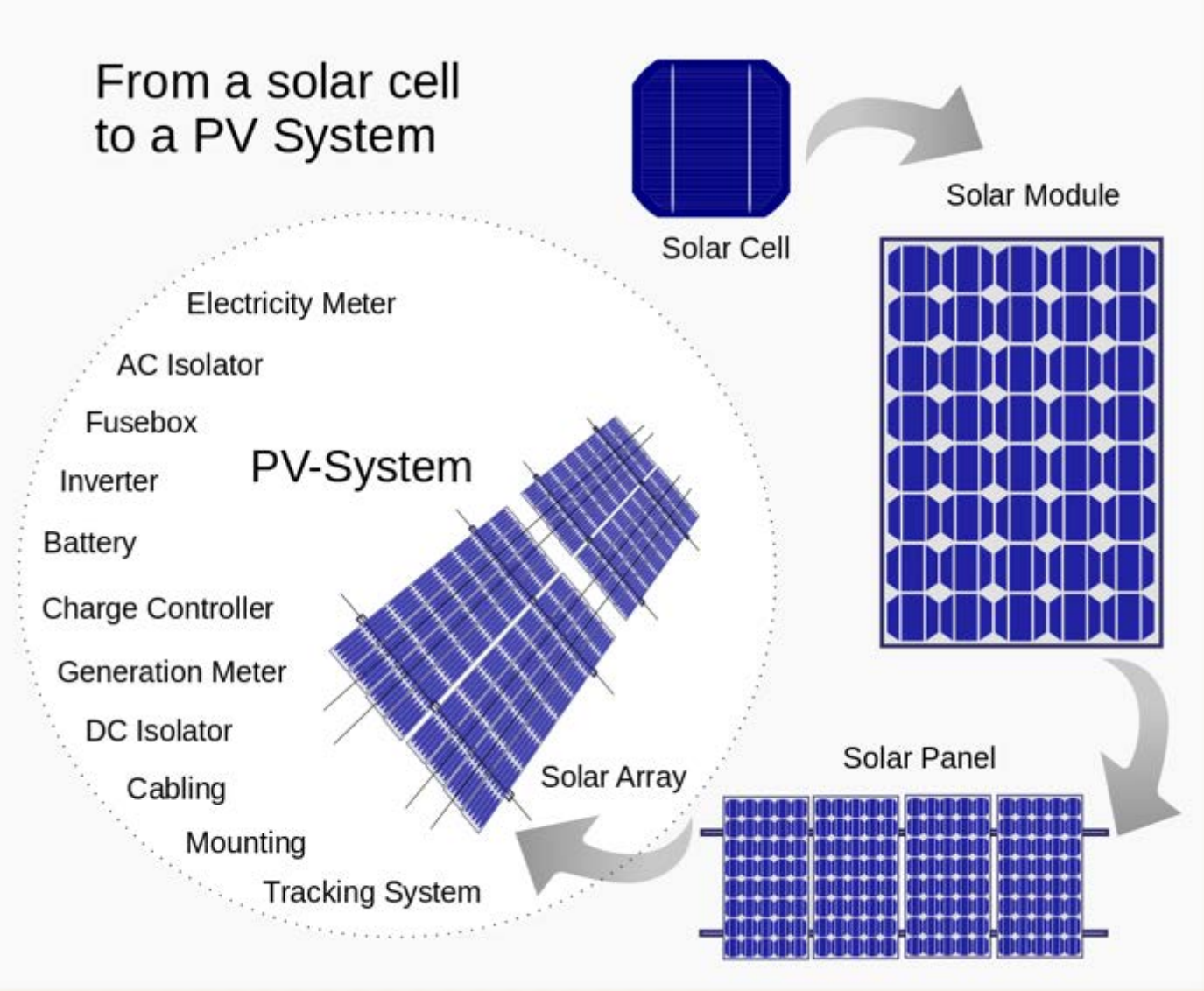
By Klaus Mueller - This image is a cutout of an image by Klaus Mueller, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=34948067alline:

SILICON CRYSTAL CELLS

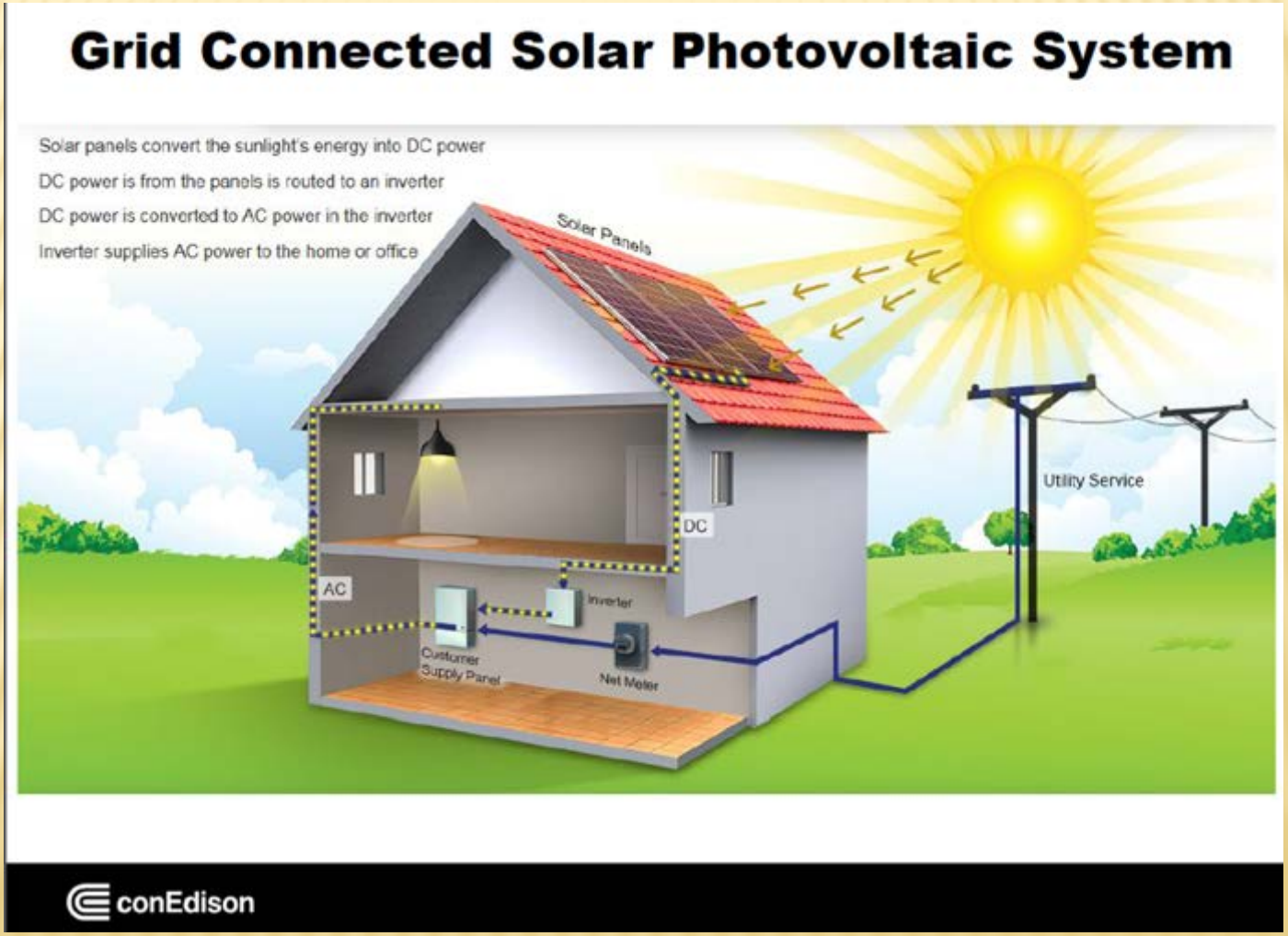
- Monocrystalline: Uniform appearance due to single crystal structure
- More efficient than Polycrystalline
- More costly to produce



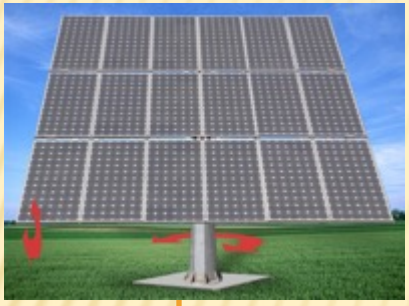
FROM CELL TO SYSTEMS



SOLAR SYSTEMS



GRID TIED SYSTEM COMPONENTS



AC Disconnect
With in 10’ of
utility meter

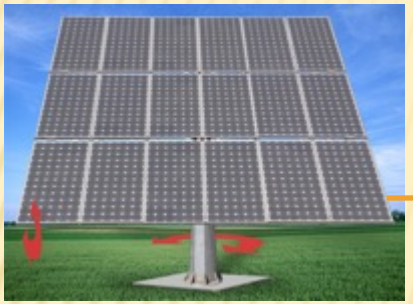
DC Disconnect

Inverter

DC

AC

GRID TIED BATTERY BACKUP



Main Panel

Charge Controller

Secure Loads panel

SYSTEM COMPONENTS

- Certifications under IEEE1547 for solar inverters
- UL1541 for inverters, and 1708 for modules
- New standards are emerging for inverters
  - CA- Rule 21/ IEEE1547.
  - Allow for more advance functions
    - Low voltage ride through
    - Dynamic controlling

SOLAR MODULES

Basic Elements

- Photovoltaic Panel
  - 250W-350W capacity each
  - 0-40V DC depending upon sunlight exposure
  - 5-10 Amps per panel
  - Produce power any time sunlight is on them
  - **Even with disconnect open, Voltage is present at panel**
  - Wired in series to increase DC Voltage and Amperage

conEdison

INVERTERS

Basic Elements

- Inverter
  - Similar to vehicle inverter
  - Converts DC to AC sine wave
  - Sine wave created exactly matches utility (unity PF)
  - Acts like an amperage source providing the house with kwh
  - Integrated AC-DC disconnect barrel switch on most models
  - Multiple sizes and models can be combined at one site

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RACKING

- Roof
  - Mechanical attachments
  - Ballasted
- Ground
  - Multiple pole
  - Single Pole
  - Ballasted
- Trackers

BALLASTED

- Flat roof or ground mounts
- Weighted to hold array in place
- No penetrations/ More Weight

GROUND MOUNTS

- Need to know soil conditions
- Very flexible configurations

ATTACHED

- Mechanical fasteners into structural members
- Flashed mounting points
- Rails to attach modules
- Integrated grounding features

TRACKERS

- Large scale installations
- Single or Dual Axis
- Increases capacity factor

BALANCE OF SYSTEM

- Meters
- Disconnects
- Combiners
- Conduit
- Wire
- Etc.

TRAINING, TOOLS, AND RULES

- Department of Labor and industry requires electrically trained persons to perform work associated with PV installation
- NEC codes guiding proper installation:
  - 690
  - 720
  - Other associated sections
- NABCEP and UL certification
- State Interconnection Standards
  - 2004 standards currently being updated
  - Small Generator Interconnection Process

SOLAR INSTALLER CERTIFICATION

- NABCEP- North American Board of Certified Energy Practitioners
- UL- Underwriter Laboratories

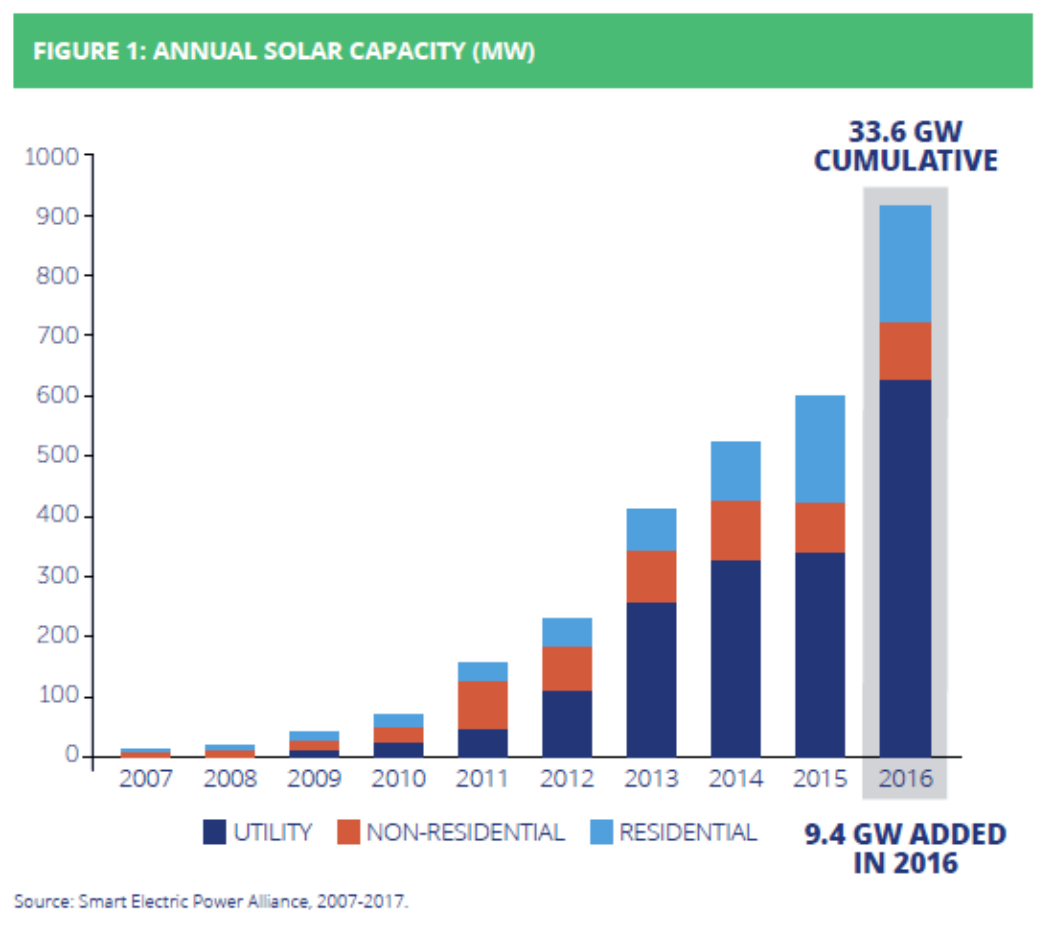
NABCEP™

Raising Standards. Promoting Confidence.

THE SOLAR MARKETPLACE TODAY

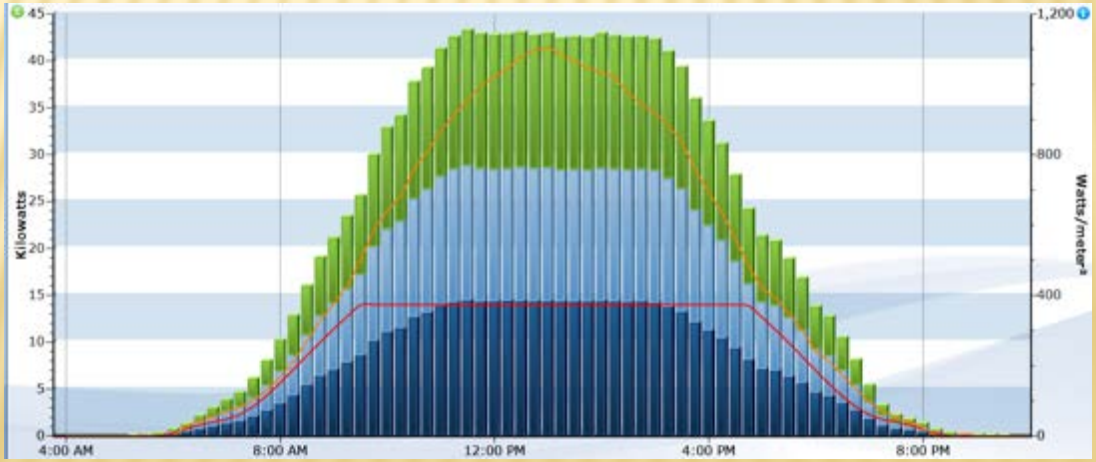
- Global demand is growing rapidly
- US demand is about 10 GW per year
- Challenges of an intermittent resource
- Falling prices bringing a competitive edge
- Solar still remains higher cost energy in many areas
- Incentives are available for consumers

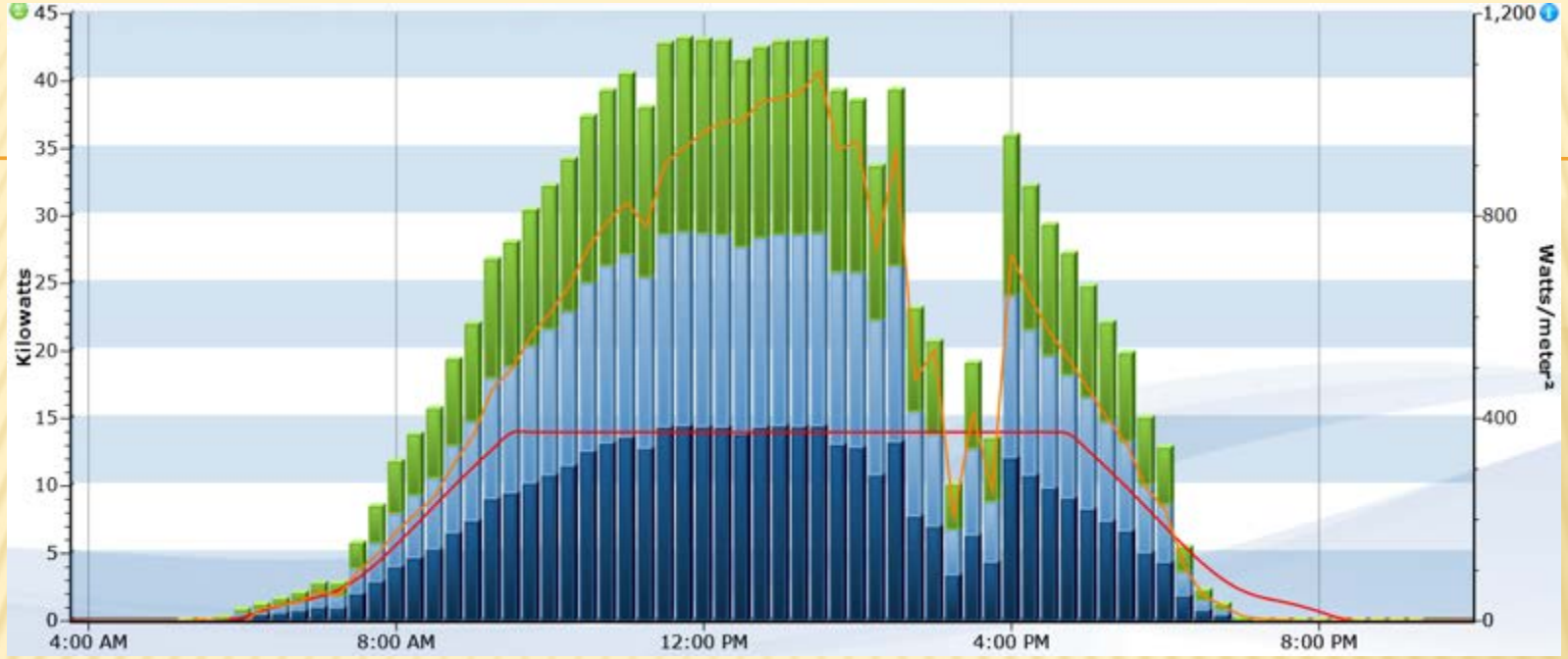
SOLAR IS GROWING

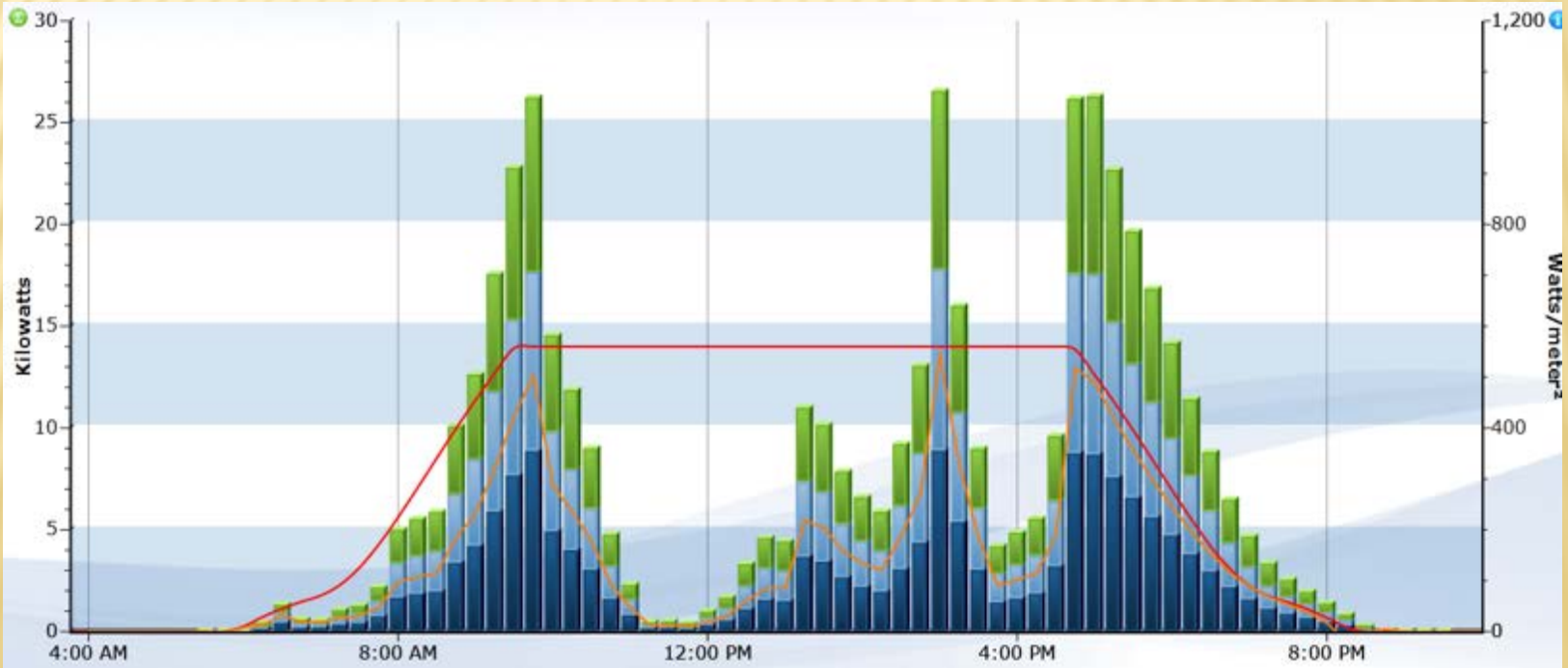


INTERMITTANT RESOURCE

- Power is produced when the sun is up, and not when it is down
- Power curves can be erratic
- As penetration of solar increases, there can be concerning effects




45
40
35
30
25
20
15
10
5
0
Kilowatts
1,200
800
400
0
Watts/meter²
4:00 AM
8:00 AM
12:00 PM
4:00 PM
8:00 PM


30
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0
Kilowatts
1,200
800
400
0
Watts/meter²
4:00 AM
8:00 AM
12:00 PM
4:00 PM
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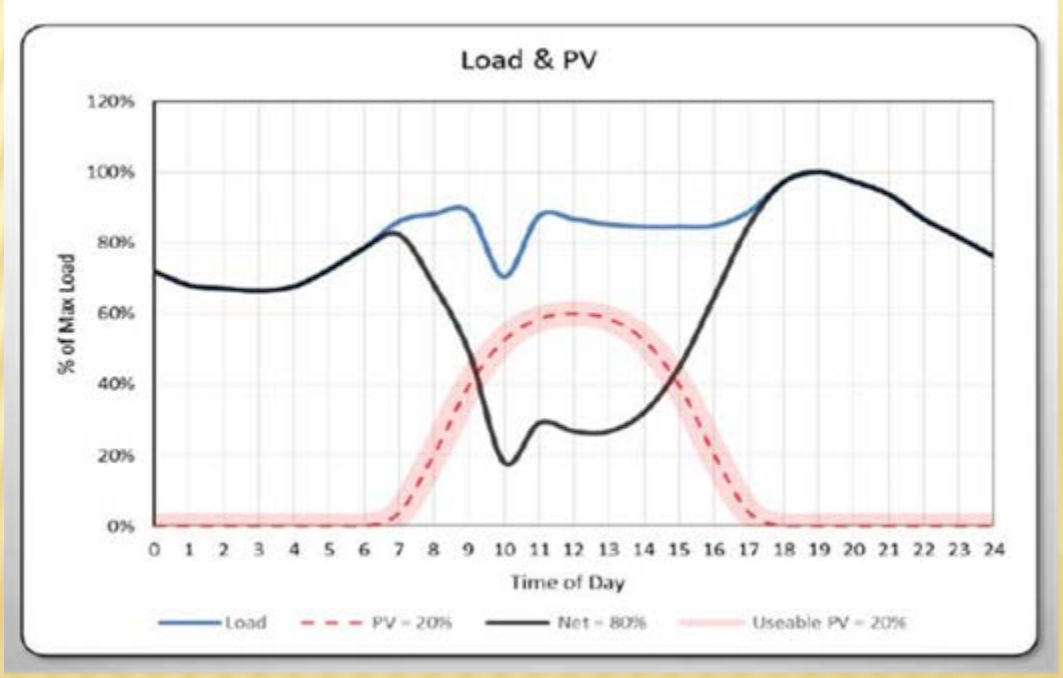
PEAK POWER MATCHING

- Solar may or may not coincide with the peak power demands
- Different across states and utility territories



STORAGE AND PEAKER PLANTS

- Peaker Plants: Natural Gas can help to overcome ‘Duck’ curve type scenarios
- Energy storage will help alleviate intermittency issues as well.

FEDERAL TAX CREDIT

- 30% of the cost of installed systems through 2019
- 26% in 2020, 22% in 2021
- 10% thereafter for businesses
- Accelerated depreciation (MACRS) for commercial
- Storage systems may also apply with stipulations on charging source.

SOLARSENSE PROGRAM

- 3 year program cycle
  - Current cycle through 2019
- Increasing yearly budget
- Estimated production based incentive
- Max $20,000
- 120% cap of previous 12 months usage
- 20 kW max system size (AC)

XCEL SOLAR*REWARDS

- Production based incentive: payments based on production of systems
- 10 years of annual payments
- $0.08/kWh
- 13.7 MW available in 2018
  - Up from 4.6 MW in 2017

NEXUS OF TECH- EVS - STORAGE

THANK YOU!

- Questions and Answers

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