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INTRODUCTION TO SOLAR: TECHNOLOGY, RESOURCES, AND POLICIES

Energy Design Conference 2023

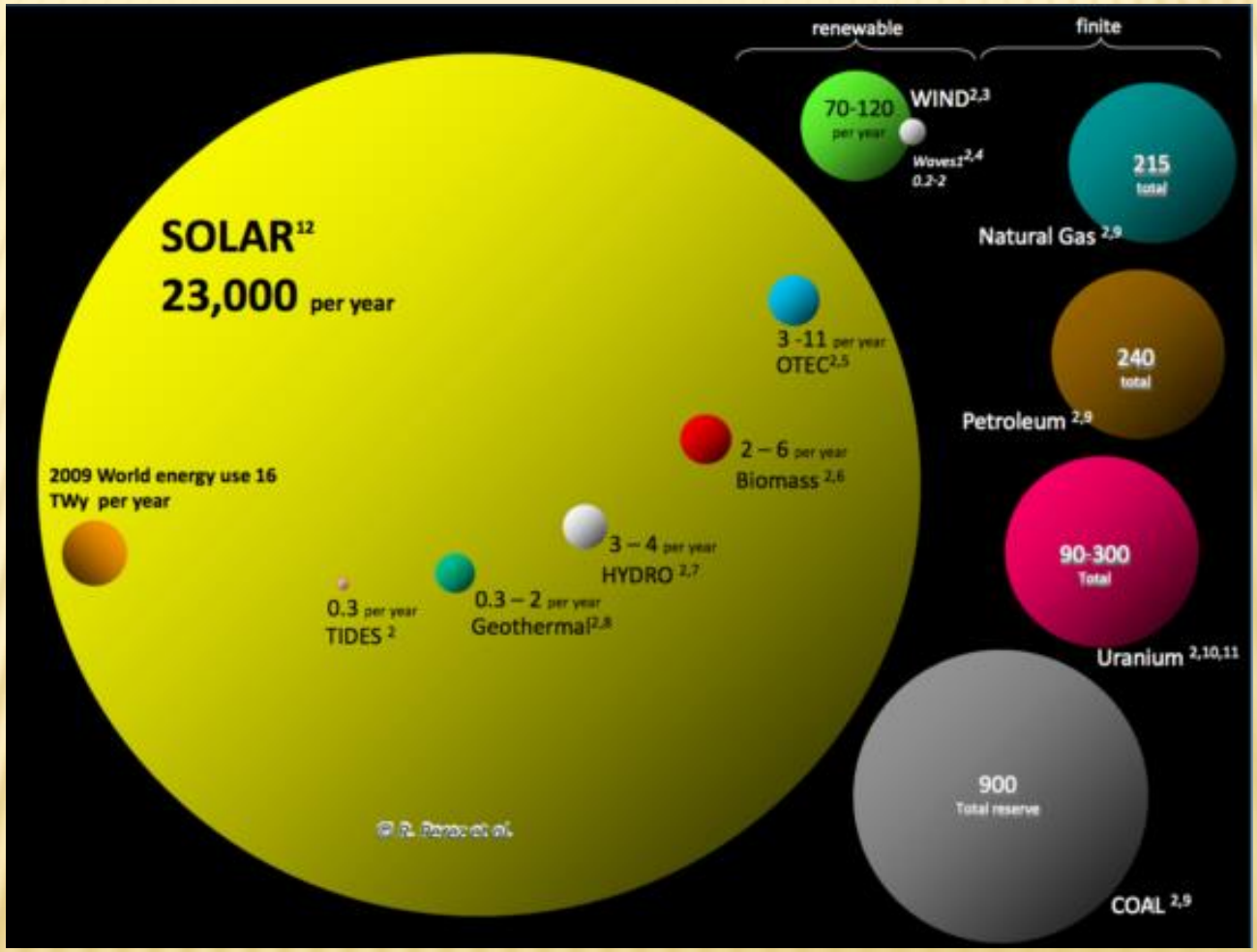
By

Paul Helstrom- Minnesota Power

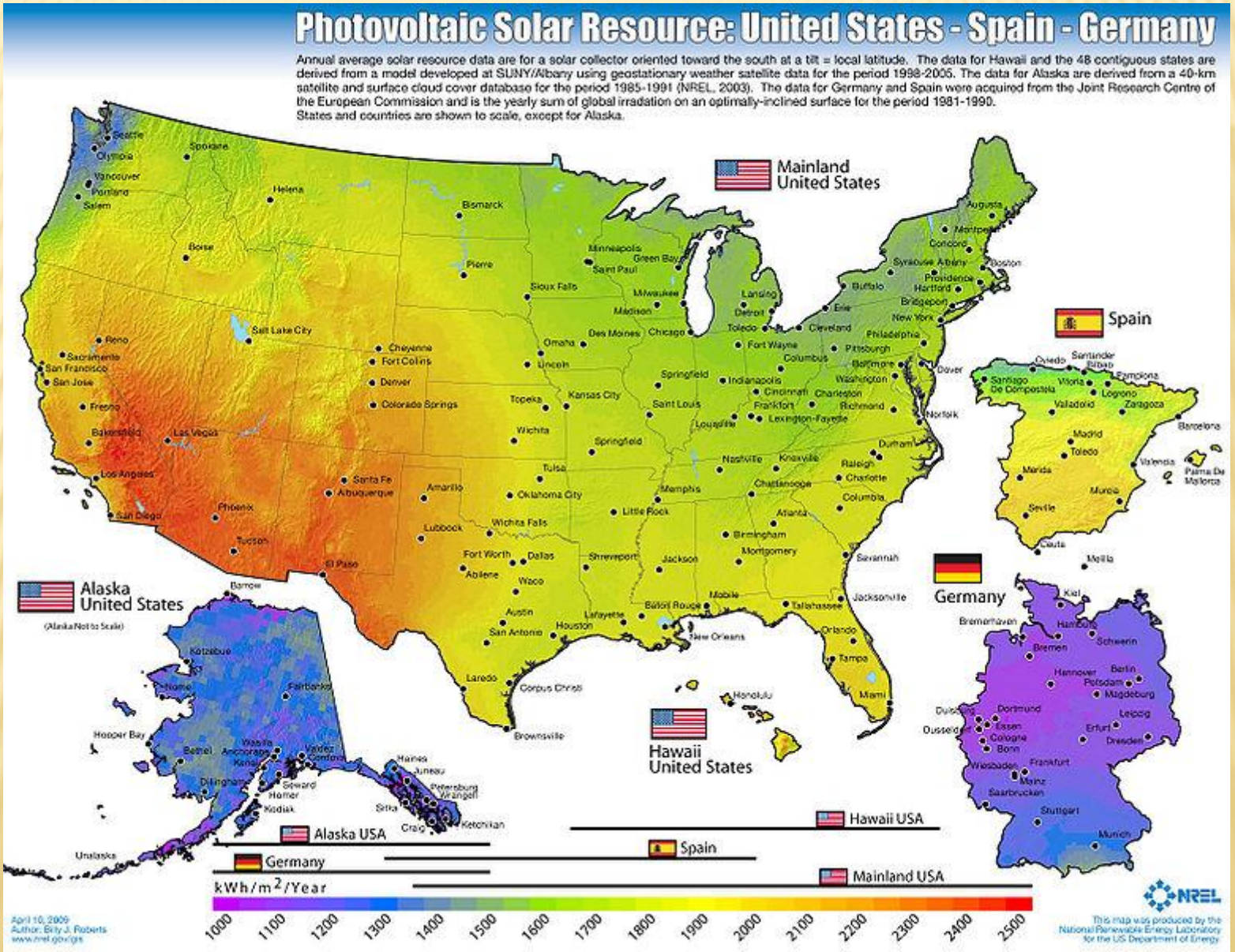
AGENDA

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

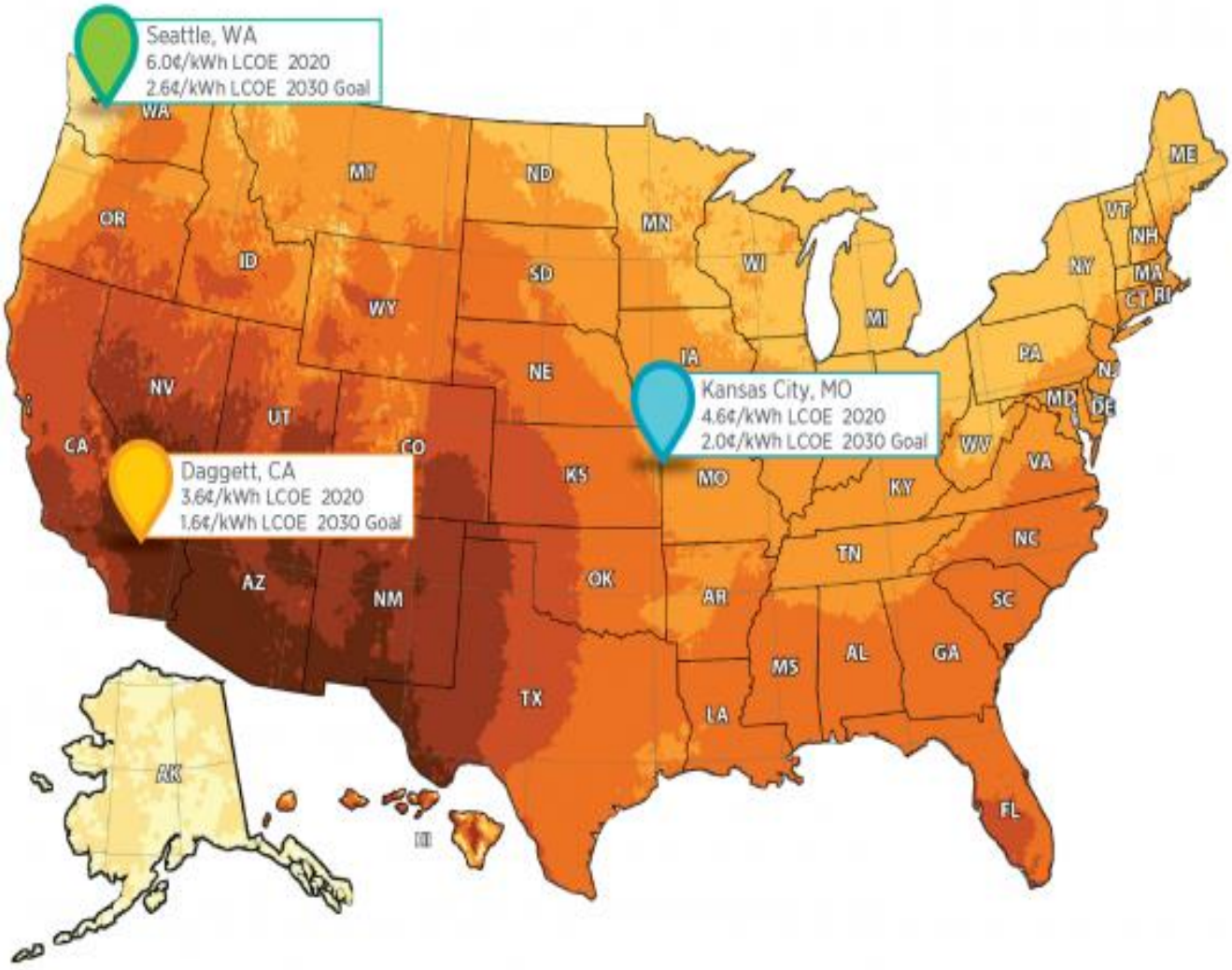
SOLAR AS A RESOURCE



US SOLAR RESOURCE



US SOLAR RESOURCE



Solar Resource Across America

kWh/m²/Day

- > 6.5
- 6.0 to 6.5
- 5.5 to 6.0
- 5.0 to 5.5
- 4.5 to 5.0
- 4.0 to 4.5
- 3.5 to 4.0
- 3.0 to 3.5
- < 3.0

Daggett, CA - **High**

Kansas City, MO - **Average**

Seattle, WA - **Low**

The amount of power that is produced by a PV system depends upon the solar resource availability (in addition to other factors like temperature and snowfall), which is location dependent. The median solar resource for the United States is represented by Kansas City, MO, while the highest solar resource is represented by Daggett, CA, and the lowest solar resource is represented by Seattle, WA.

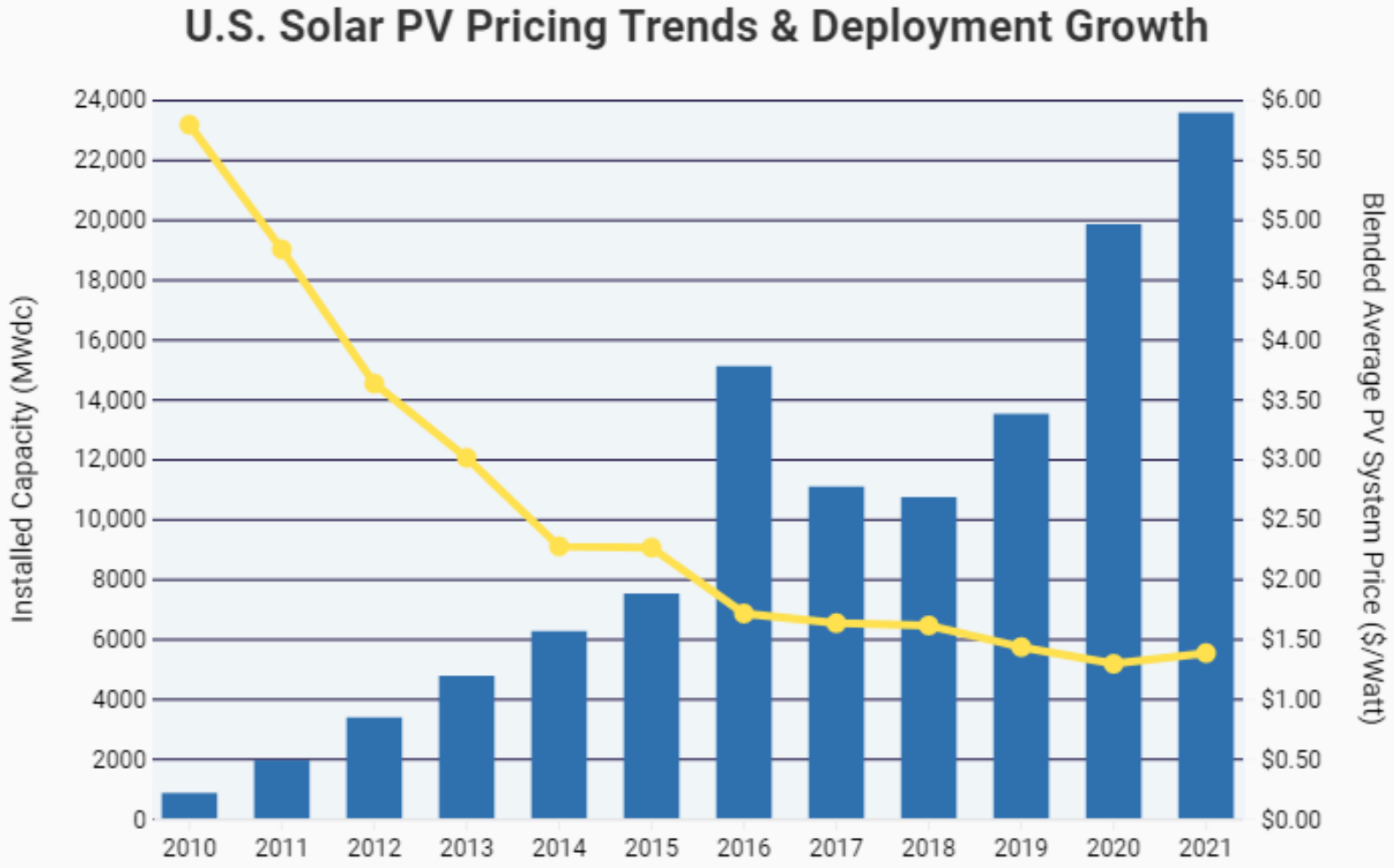
HISTORY OF SOLAR

- Solar has been used for millennia – primarily for heat and fire
- Photovoltaic effect first described: 1839
  - Edmond Becquerel
- 1954- First C-Si solar cells- Bell Labs
  - 4% efficient- 11% achieved later
- Satellites
- 1980- Arco solar first company to produce 1 MW of solar PV cell
  - 1983 Worldwide pv prod = 21 MW

THE SOLAR MARKETPLACE TODAY

- Global demand is growing rapidly
- US demand was about 18 GW in 2022
- 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

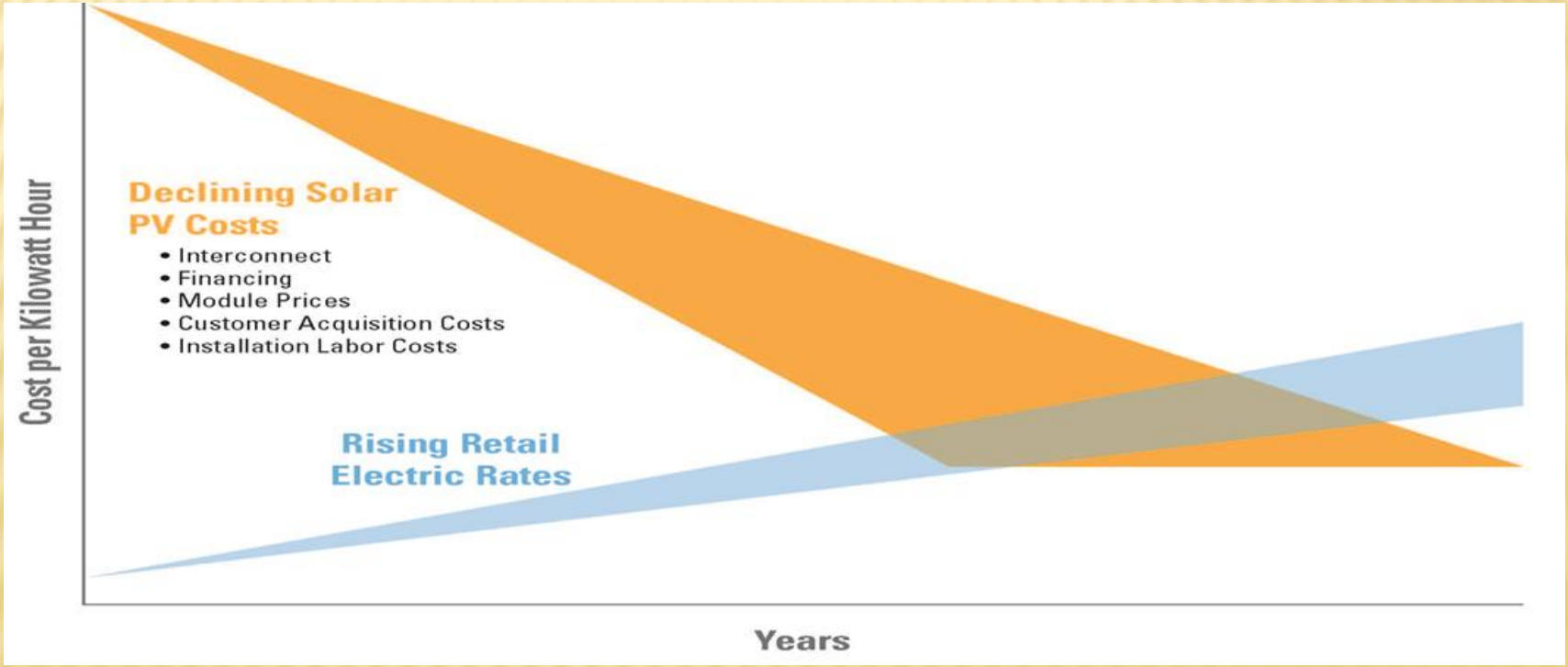
SOLAR IS GROWING



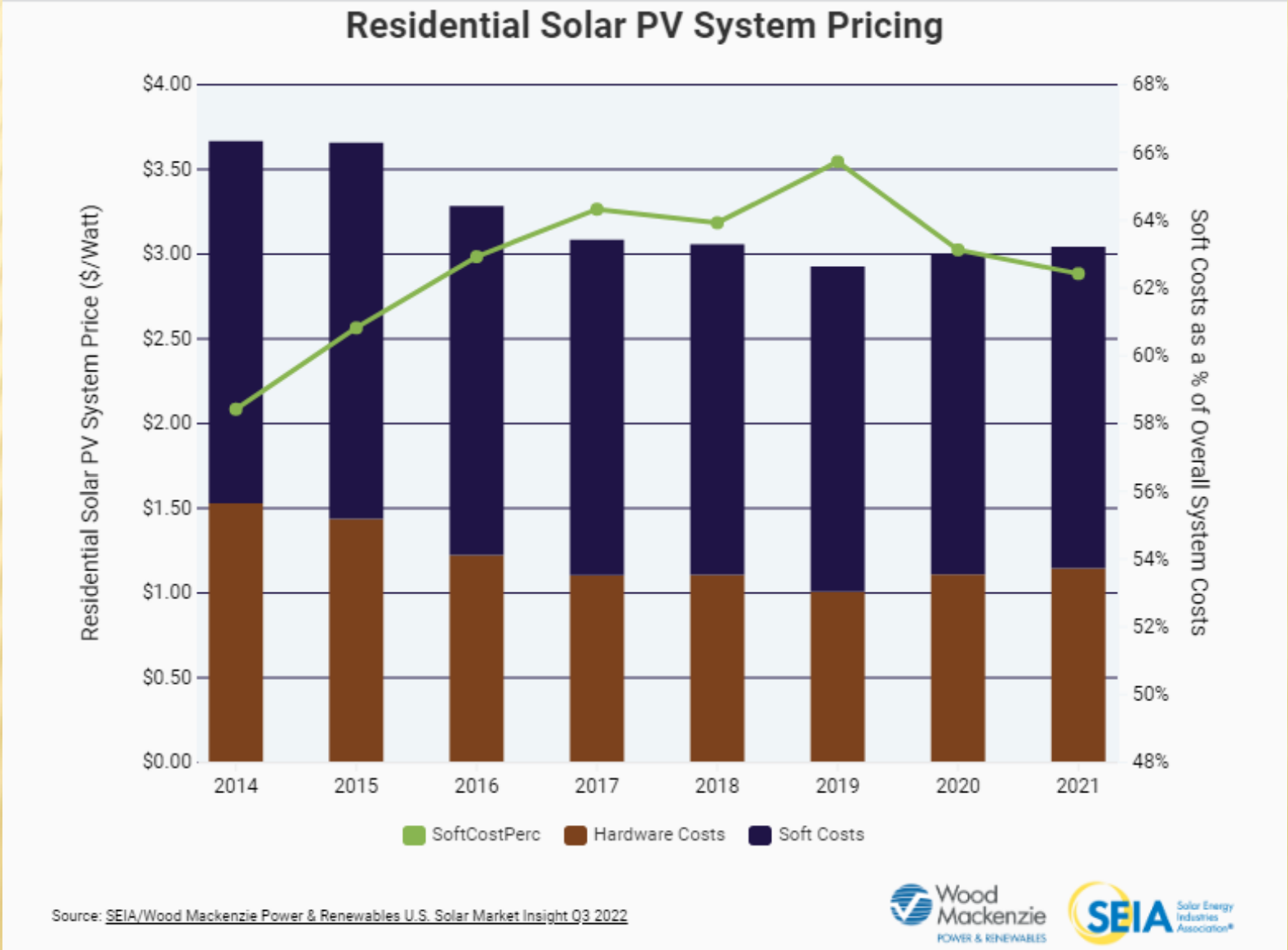
Source: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight Q3 2022

COST OF SOLAR

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



COST OF SOLAR

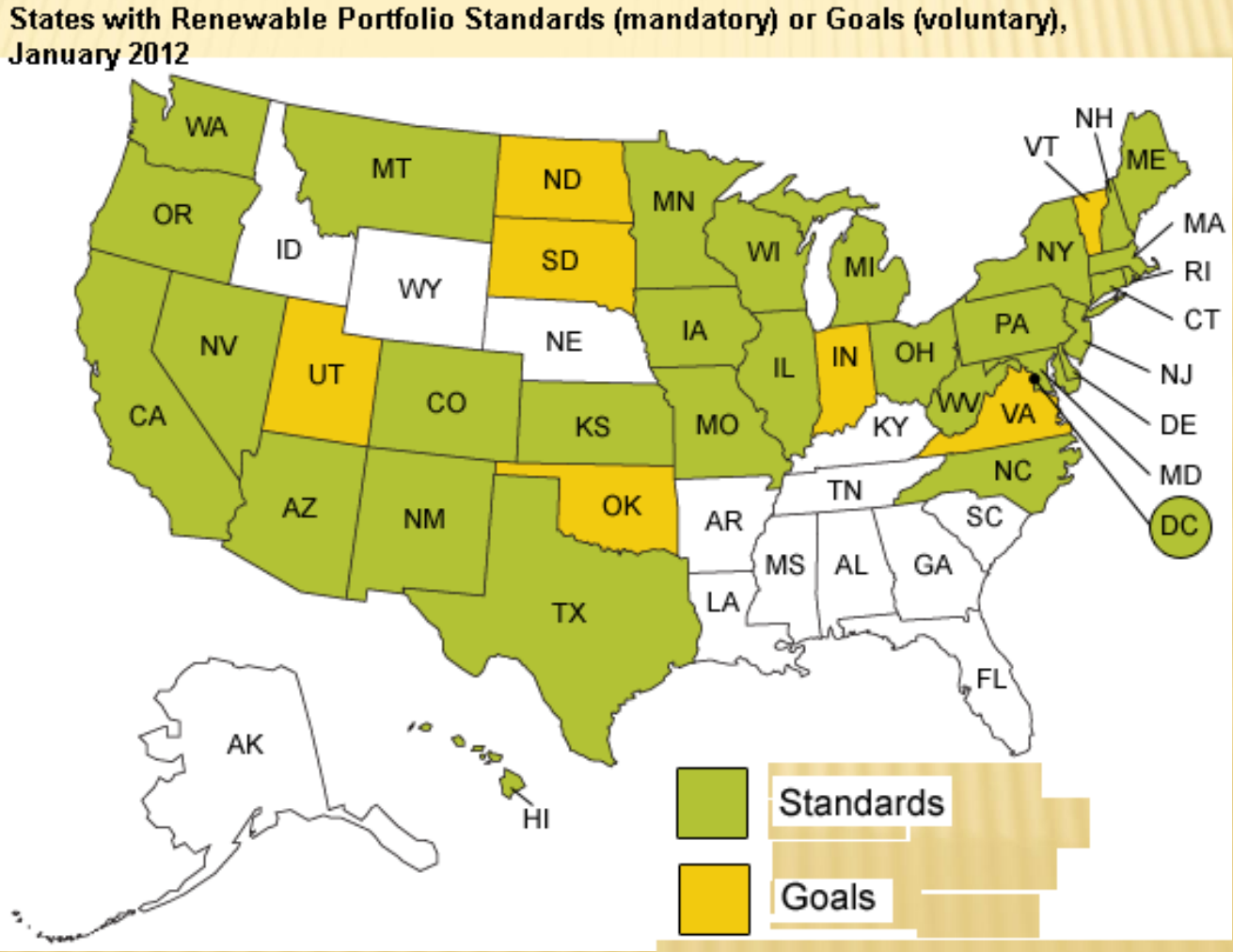


Source: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight Q3 2022

POLICIES DRIVING SOLAR

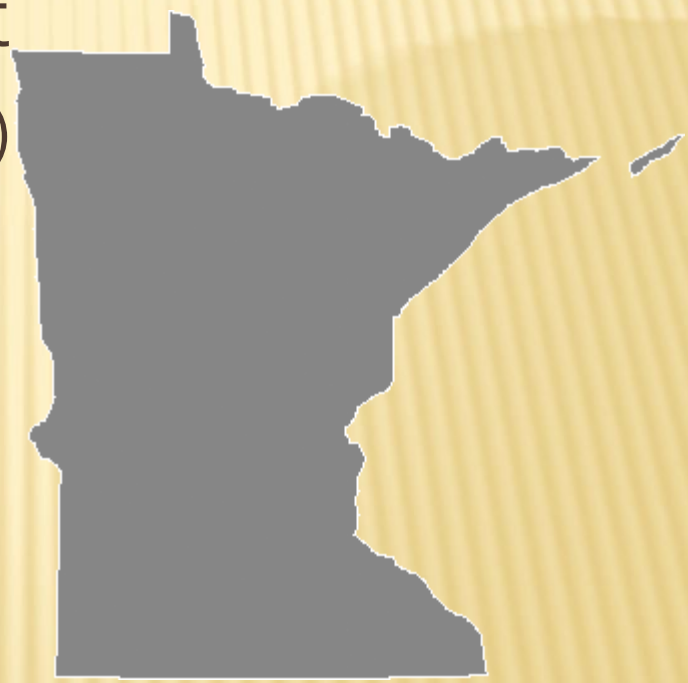
- Global:
  - Germany: EnergieWende
  - China: 5 Year plans
  - USA: state level RPSs
  - Others
- Public Utilities Regulatory Policies Act 1978
- Net Metering
- Community Solar Gardens
- State Mandates

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
- 100% by 2040
  - Passed in 2023



2013 Minnesota Solar Legislation

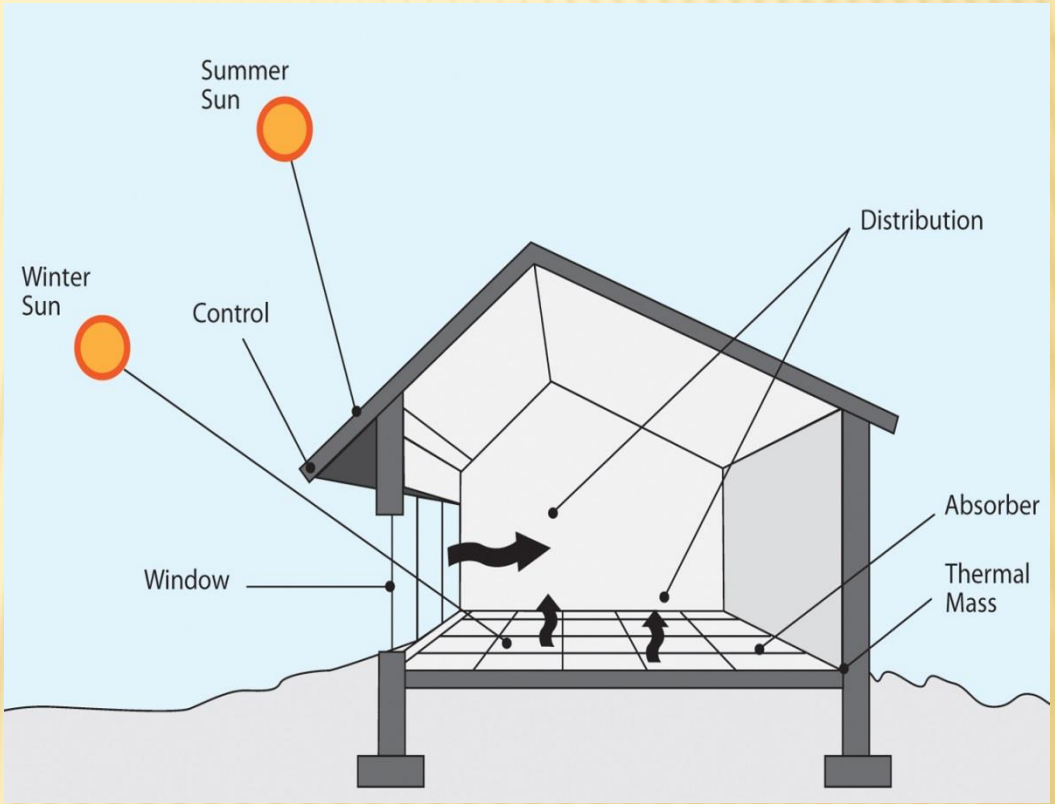
Renewable Energy Standard (RES)	**Unchanged**
Solar Energy Standard (SES)	**1.5% of Retail Sales by 2020** *(excludes mining & paper industry)*
Net Meter	**1 MW Limit** *(not to exceed 120% of usage)*
Solar Value Rate	**Value of Solar (VOS)** *(Optional for IOU's)*
Community Solar Gardens	**Xcel Required,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

SOLAR TECHNOLOGY TYPES

- 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

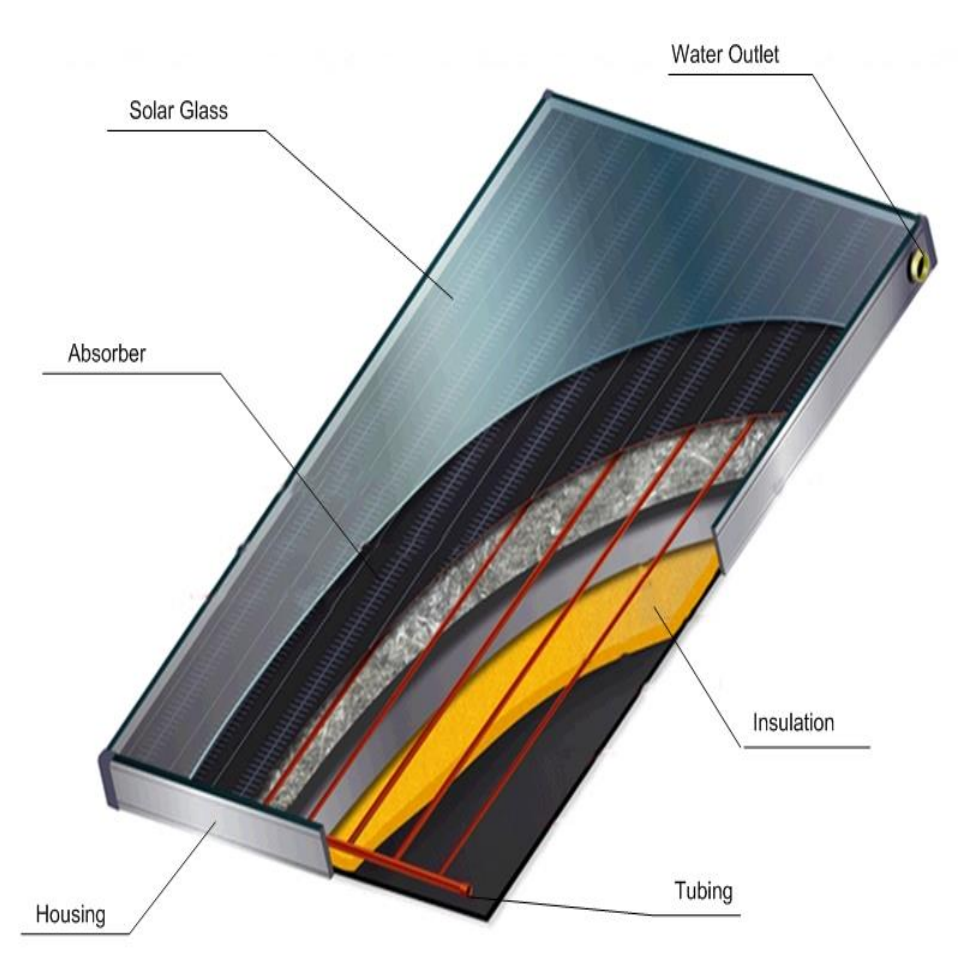
- Design types
  - Batch
  - Pressurized
  - Drain back
- System components
  - Collectors
  - Pumps
  - Pipes
  - Storage tanks
  - Controls
  - Sensors

BATCH SYSTEMS

- Used in warmer climates
- Small footprint

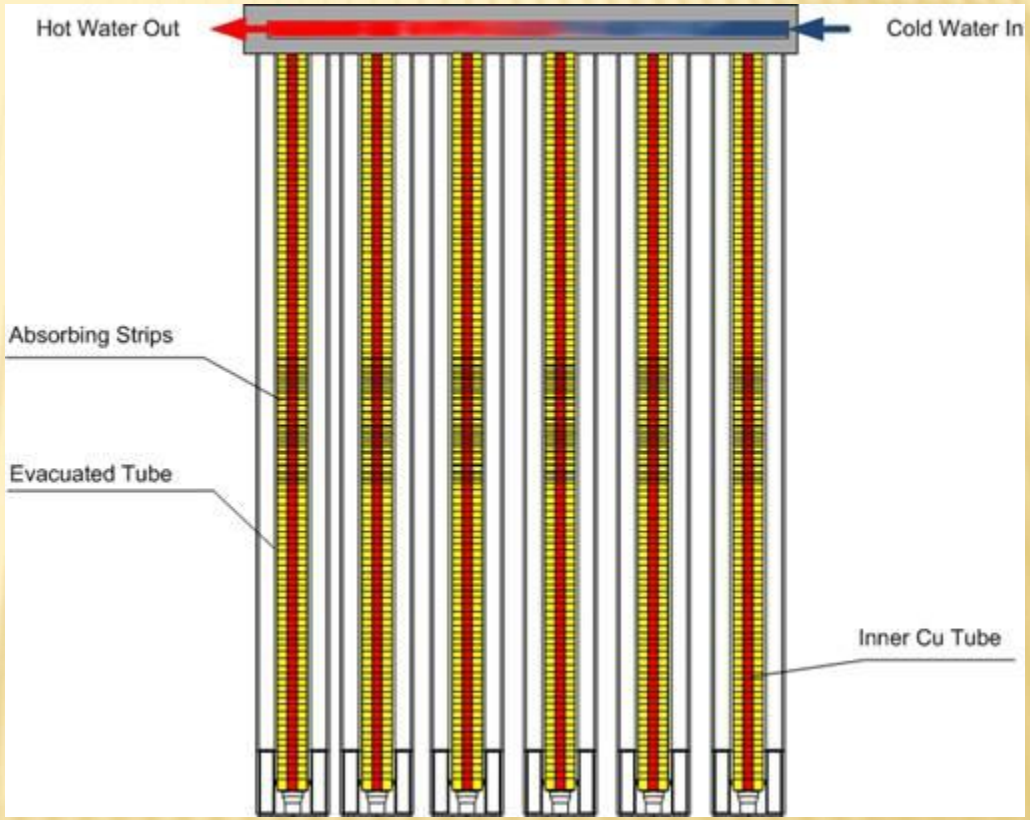
FLAT PLATE

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



EVACUATED TUBES

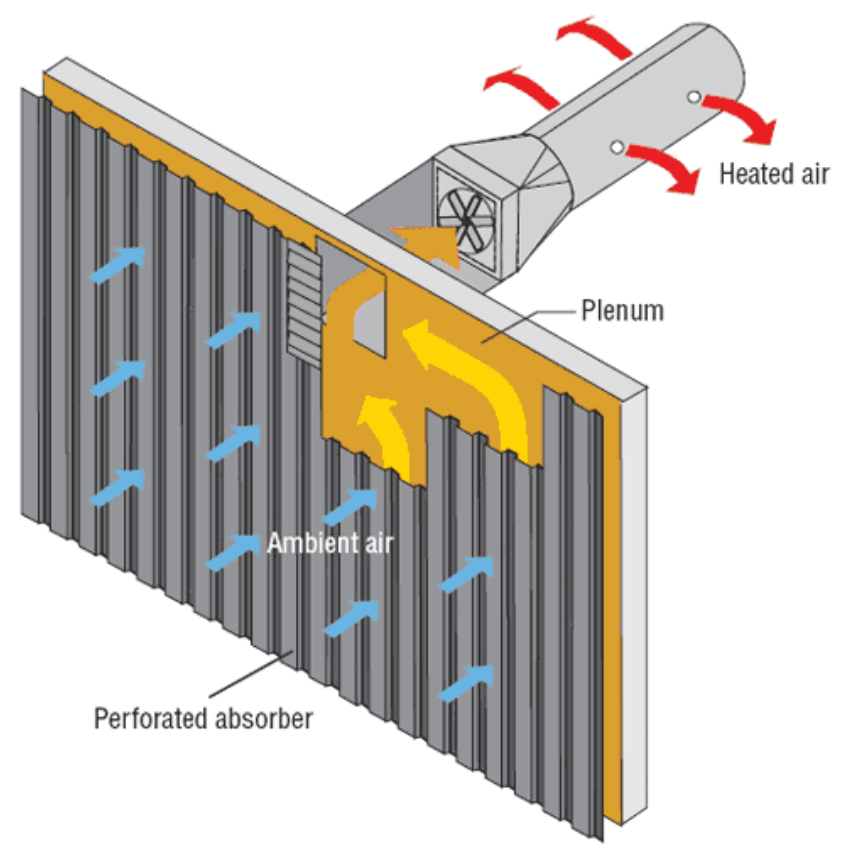
- Vacuum sealed chamber around a specialized metal collector
- Top manifold to transfer heat to coolant loop
- Effective in very cold conditions
- Vacuum is key



SOLAR THERMAL- HOT AIR

- Space heating
- Transpired air- pre conditioning
- Process heat
  - Breweries

SOLAR WALLS- TRANSPIRED AIR



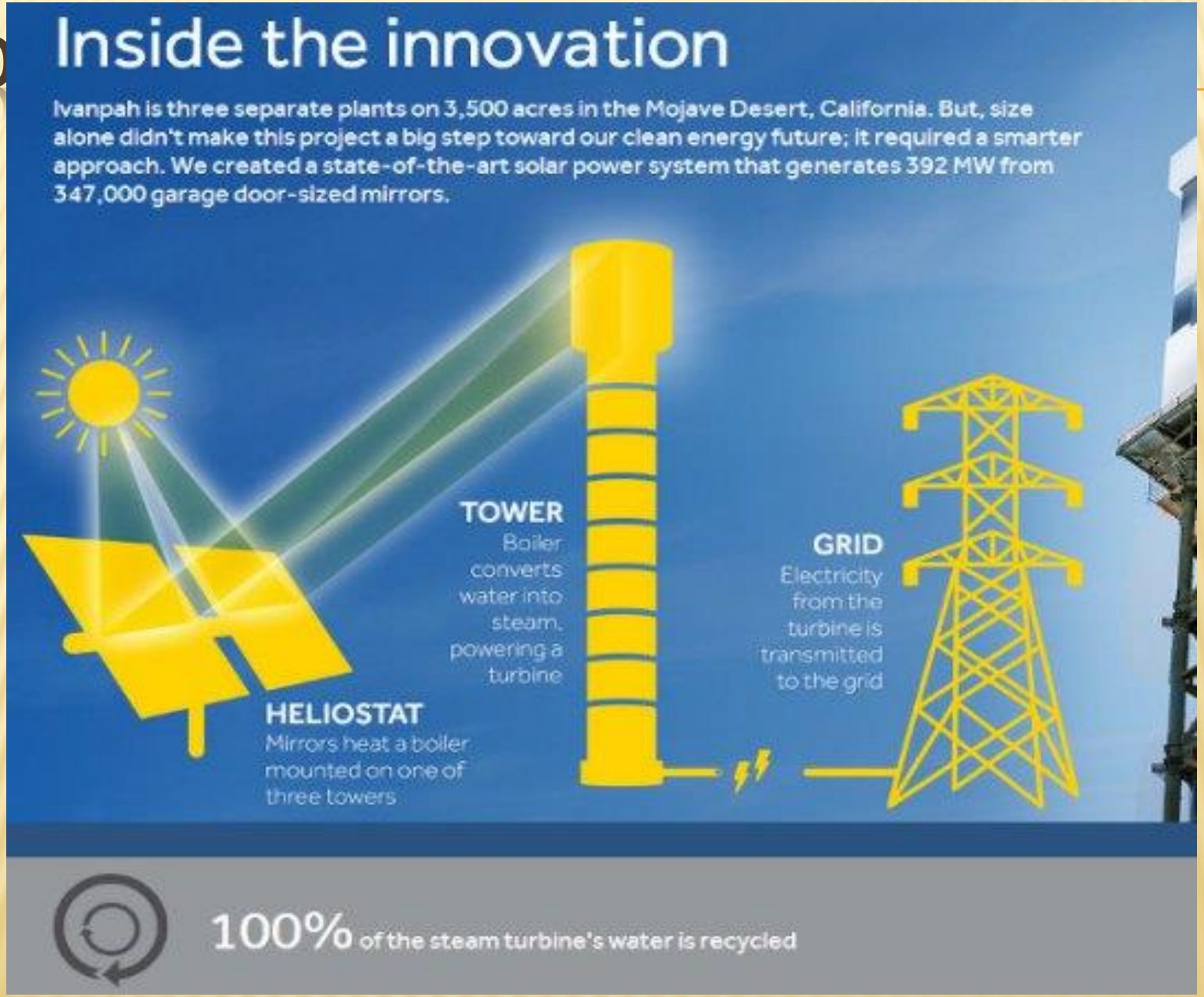
SOLAR THERMAL- GENERAL

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

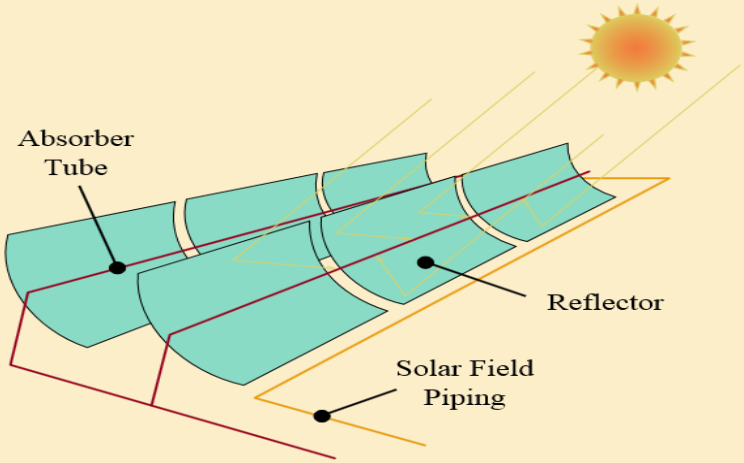
SOLAR ELECTRIC- THERMAL

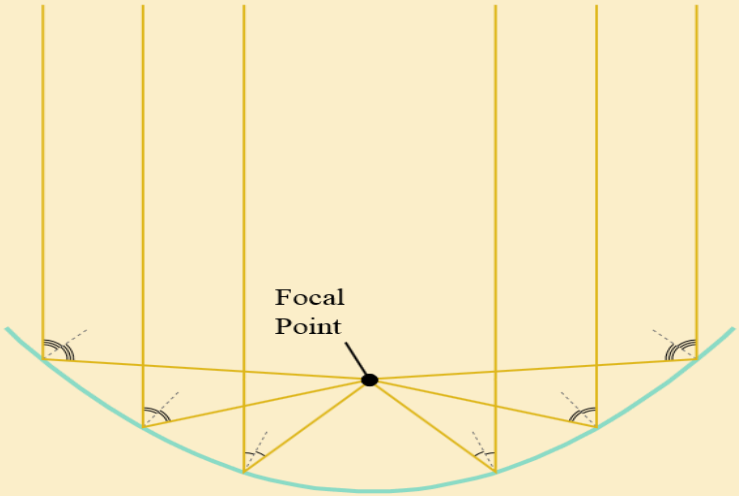
- Concentrating the sun to produce high levels of heat to create steam for power production
- Parabolic Trough and Power Towers

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

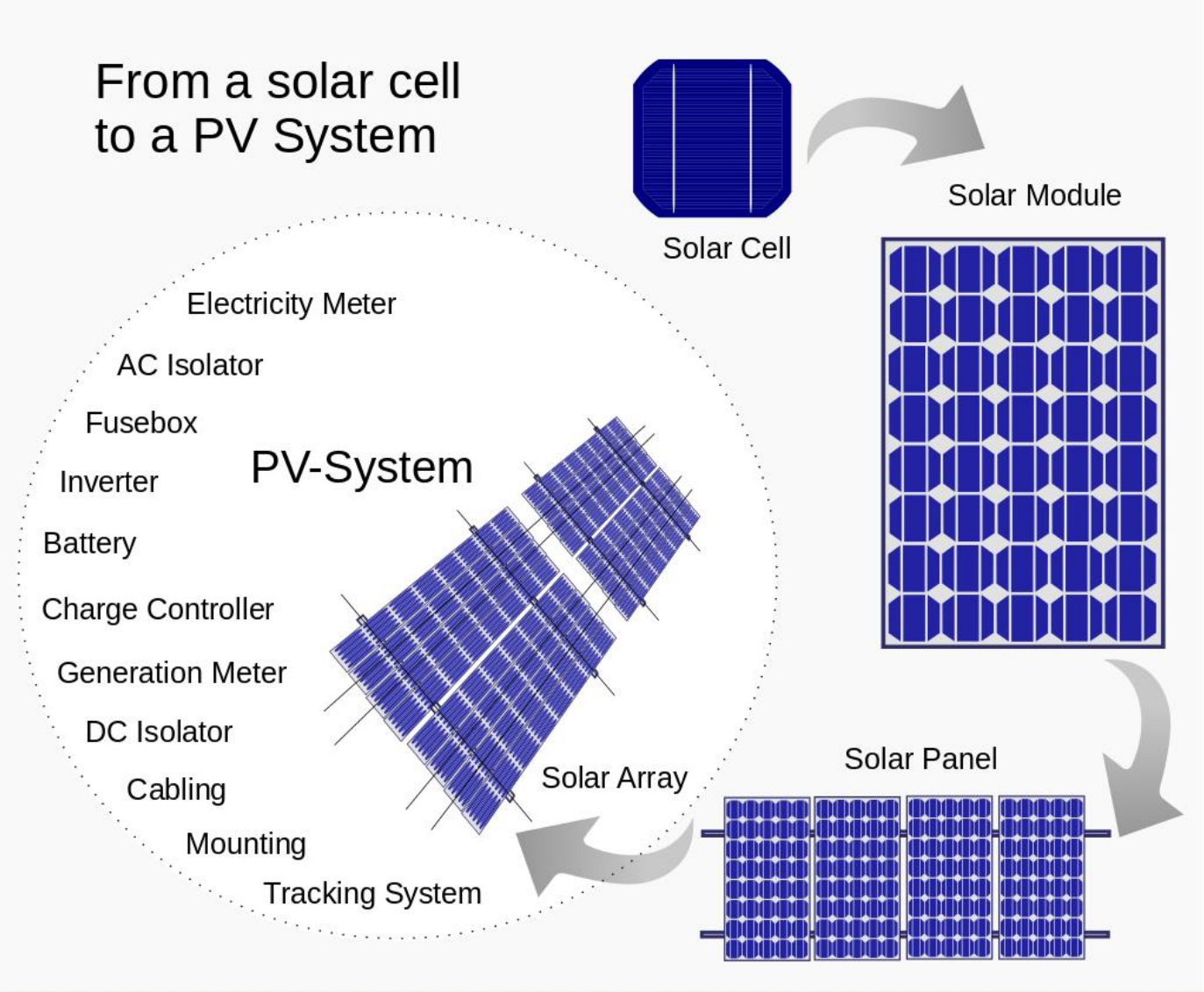




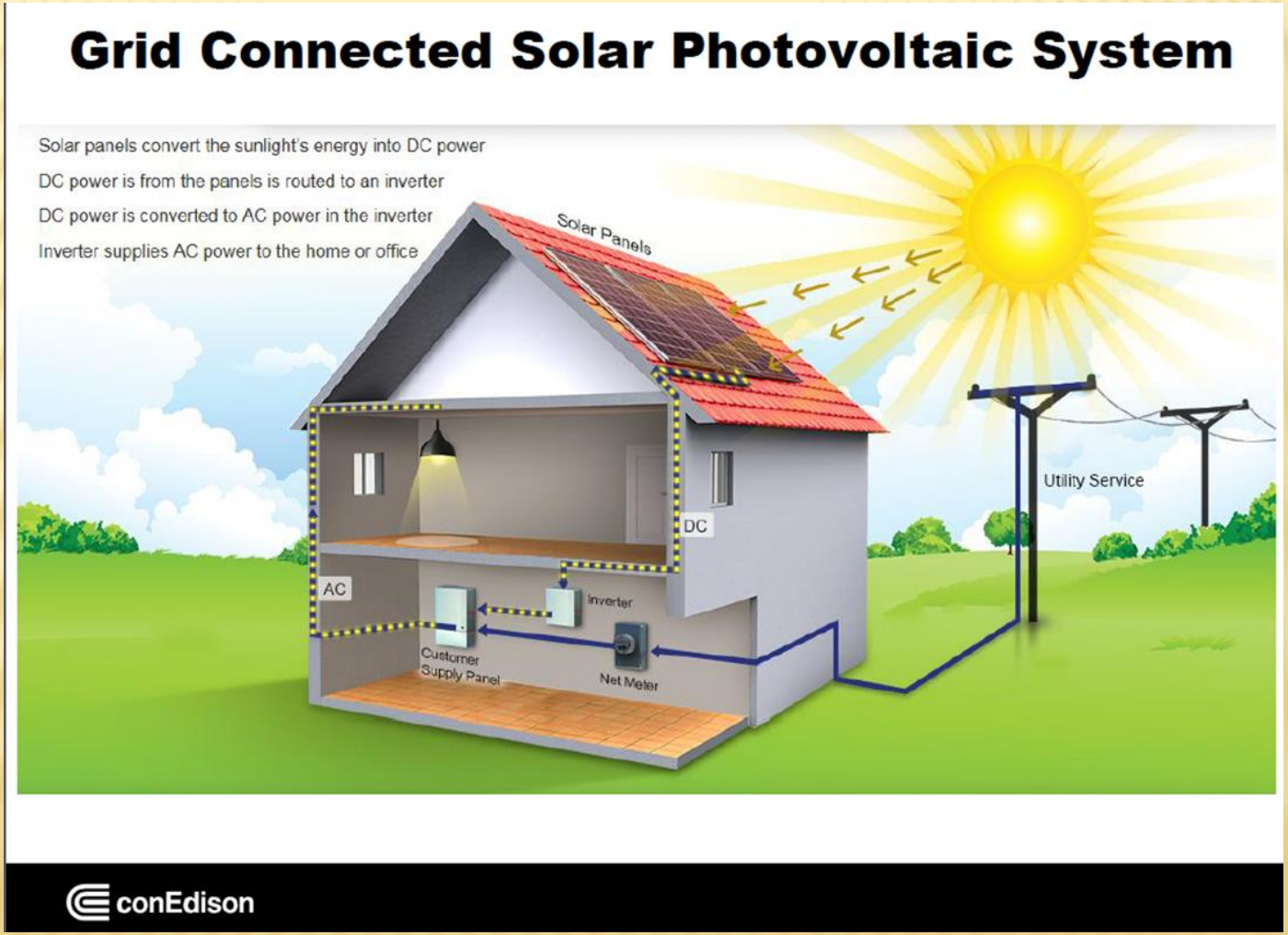
PHOTOVOLTAIC EFFECT

- 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

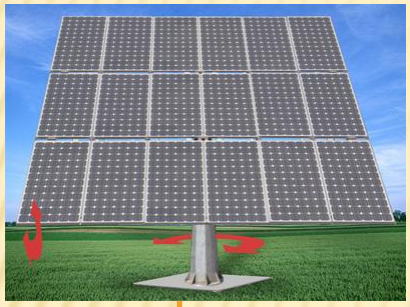
FROM CELL TO SYSTEMS



SOLAR SYSTEMS



GRID TIED SYSTEM COMPONENTS



AC Disconnect
With in 10’ of
utility meter

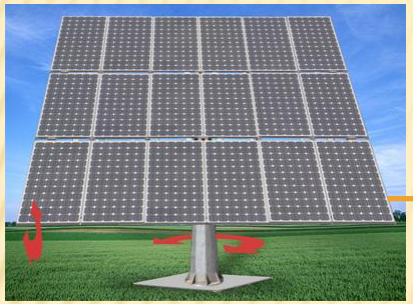
DC Disconnect

Inverter

DC

AC

GRID TIED BATTERY BACKUP



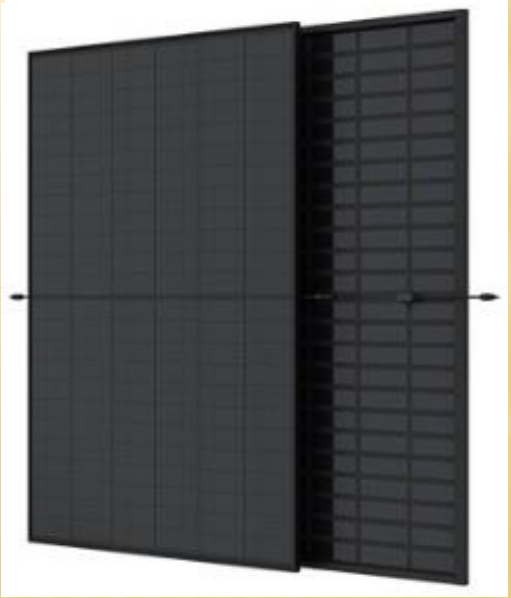
Main Panel

Charge Controller

Secure Loads panel

SOLAR MODULES

- 20%+ Efficiency
- Fairly standard sizes
- ~40”W x 70”H
- 350-450 watt
  - Growing - +500watts
- Solar cell evolution
  - Half cell, PERC, etc
- Bifacial modules



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

RACKING

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

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

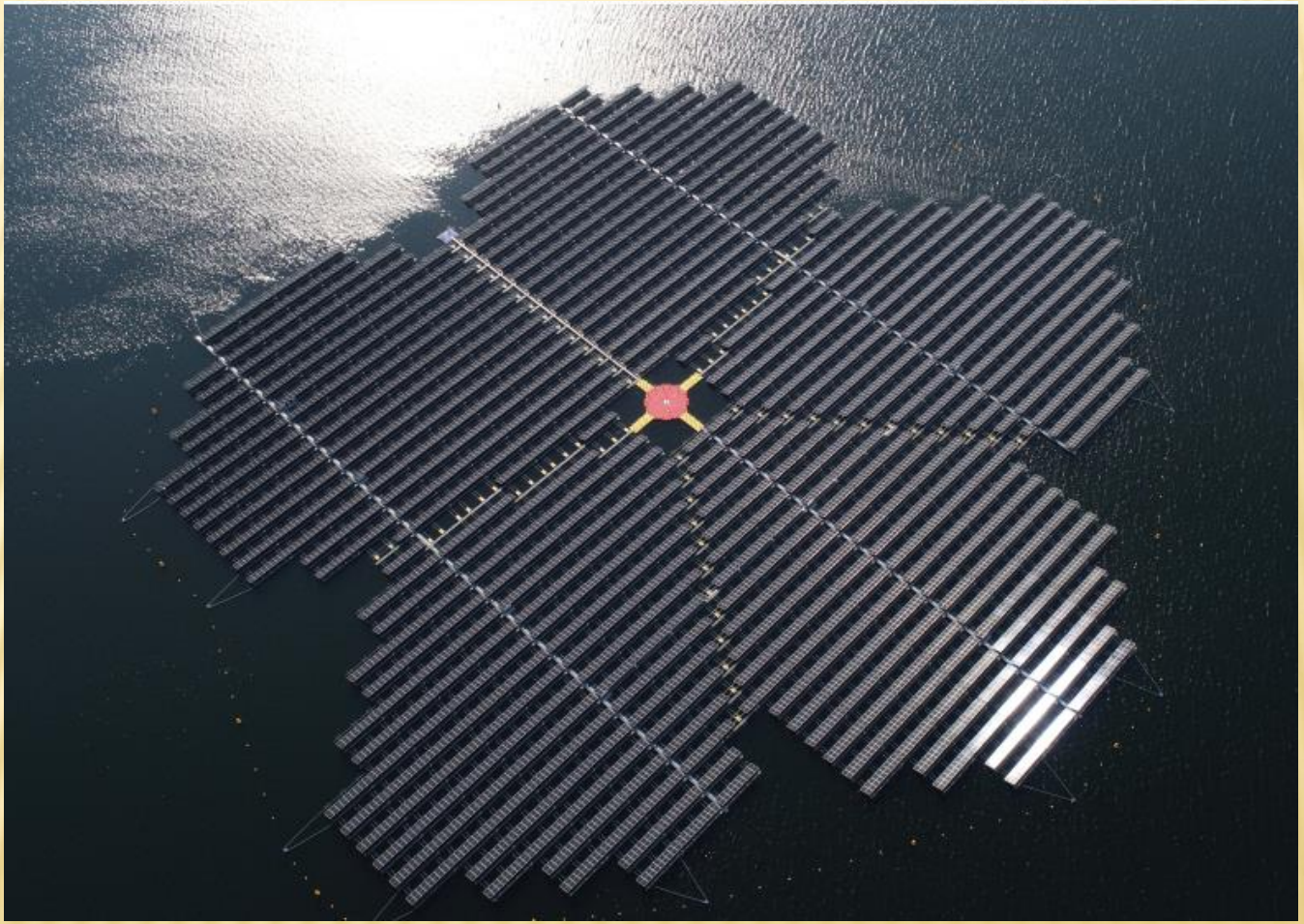
ATTACHED

- 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

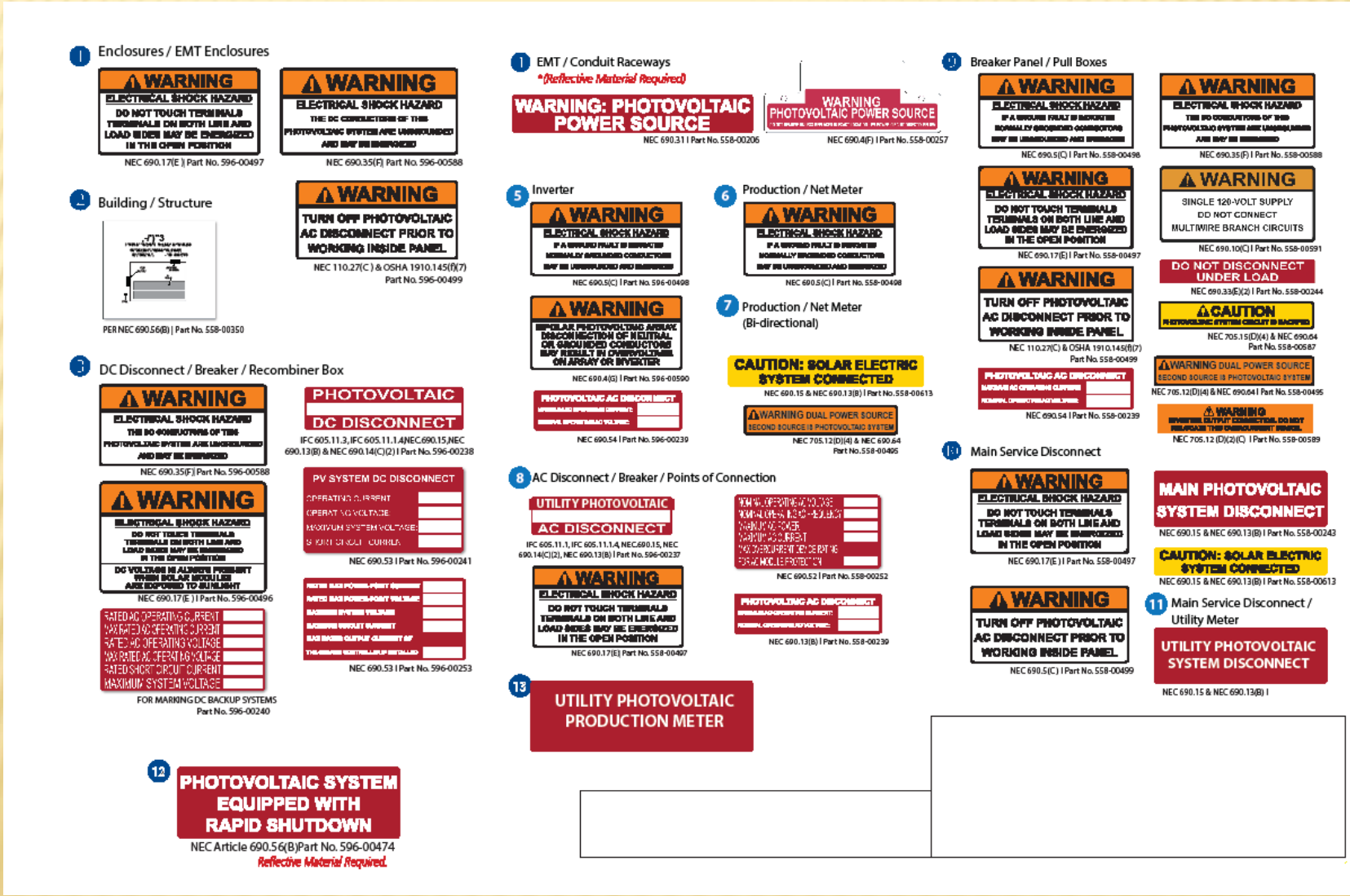
FLOATING SOLAR ARRAYS



BALANCE OF SYSTEM

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

LABELS- LOTS OF LABELS



SYSTEM COMPONENTS CERTIFICATIONS

- Certifications under IEEE1547 for solar inverters
- UL1541 for inverters, and 1708 for modules
- New standards are emerging for inverters
  - IEEE1547-2018 for MN TIIR.
  - Allow for more advance functions
    - Low voltage ride through
    - Dynamic controlling

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
  - MnDIP Process

SOLAR INSTALLER CERTIFICATION

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

NABCEP™

Raising Standards. Promoting Confidence.

CODE COMPLIANCE ELEMENTS

- Rapid shutdown
- Grounding
- Labeling
- Safety/isolation – Anti-islanding
- Roof set backs

SOLAR PHOTOVOLTAICS AND FIRE SAFETY

Photo Credit: Greentech Media 9/19/2013

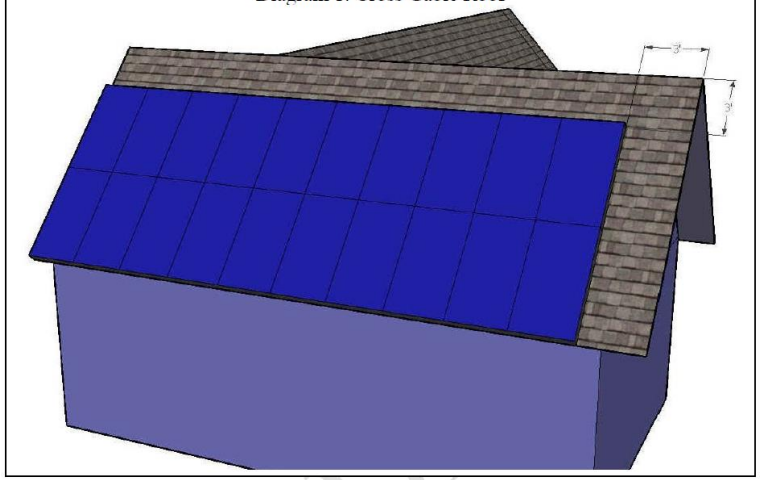
PV SAFETY IMPROVEMENTS

- NEC Code requirements:
  - Conduit requirements for DC wiring
  - Labeling requirements
    - Better information
    - More information
    - More locations on the system
  - Rapid Shut Down systems
    - Requirement in 2015 code
    - Requires shut down within 10 seconds from time of activation to within 10’ of array, or within 5’ of entrance into the building.

RECOMMENDED BEST PRACTICES

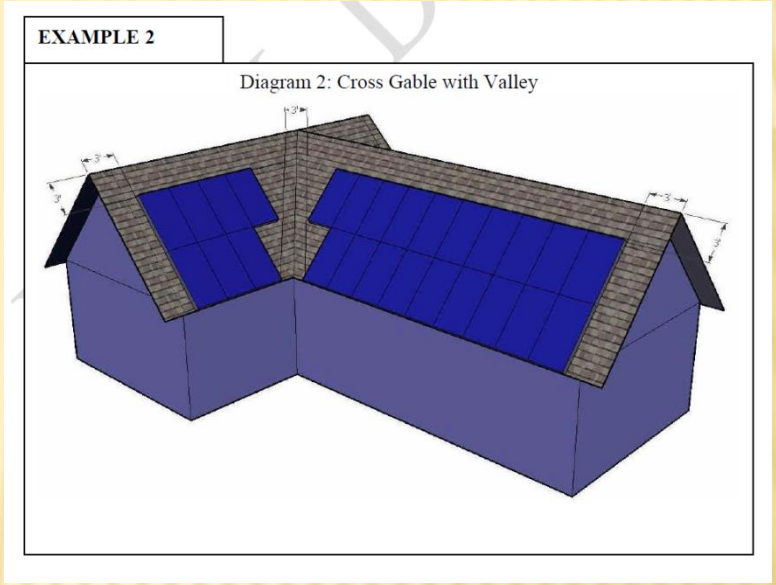
EXAMPLE 1

Diagram 1: Cross Gable Roof



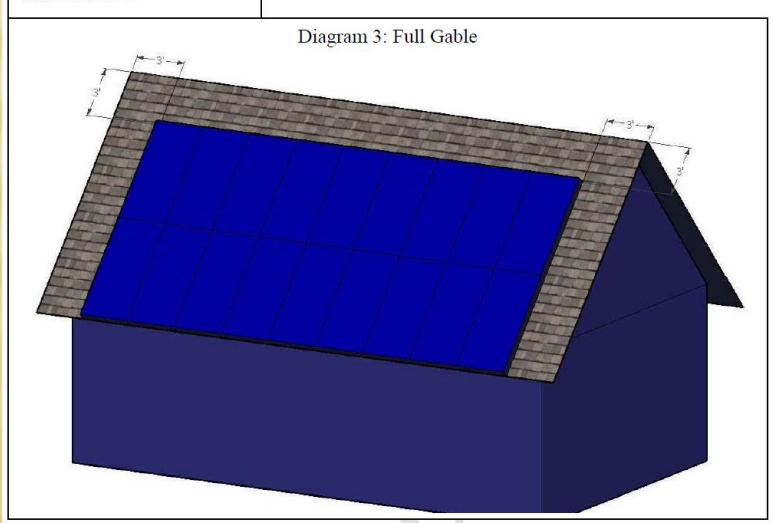
EXAMPLE 2

Diagram 2: Cross Gable with Valley



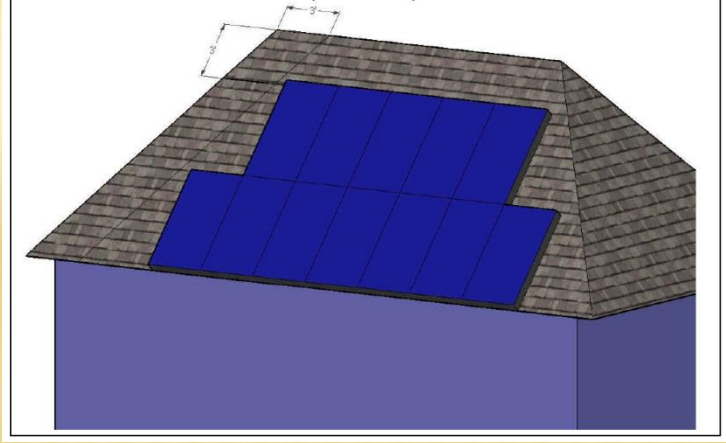
EXAMPLE 3

Diagram 3: Full Gable



EXAMPLE 4

Example 4: Full Hip Roof



INTERCONNECTION PROCESS- MN DIP

- Universal application and agreements requirements for Minnesota
- Technical stipulations vary utility to utility
  - Technical Standard Manual- Utility specific requirements
  - Technical Interconnection and Interoperability Requirements- TIIR – Statewide
- Interconnection Agreement:
  - MnDIA
  - Uniform Statewide Contract- USC

INTERCONNECTION PROCESS

- Working in different utility jurisdictions:
  - Be aware of differing processes
  - Be aware of different technical requirements
  - Call and ask questions

INTERCONNECTION PROCESS

- Examples:
  - Production meters:
    - MP, CLP, ECE require them
    - Lake Country does not
    - Pay attention to how to wire them
      - Line side for MP
      - Load side for CLP and ECE
  - Subtractive metering
    - Not allowed with solar customers

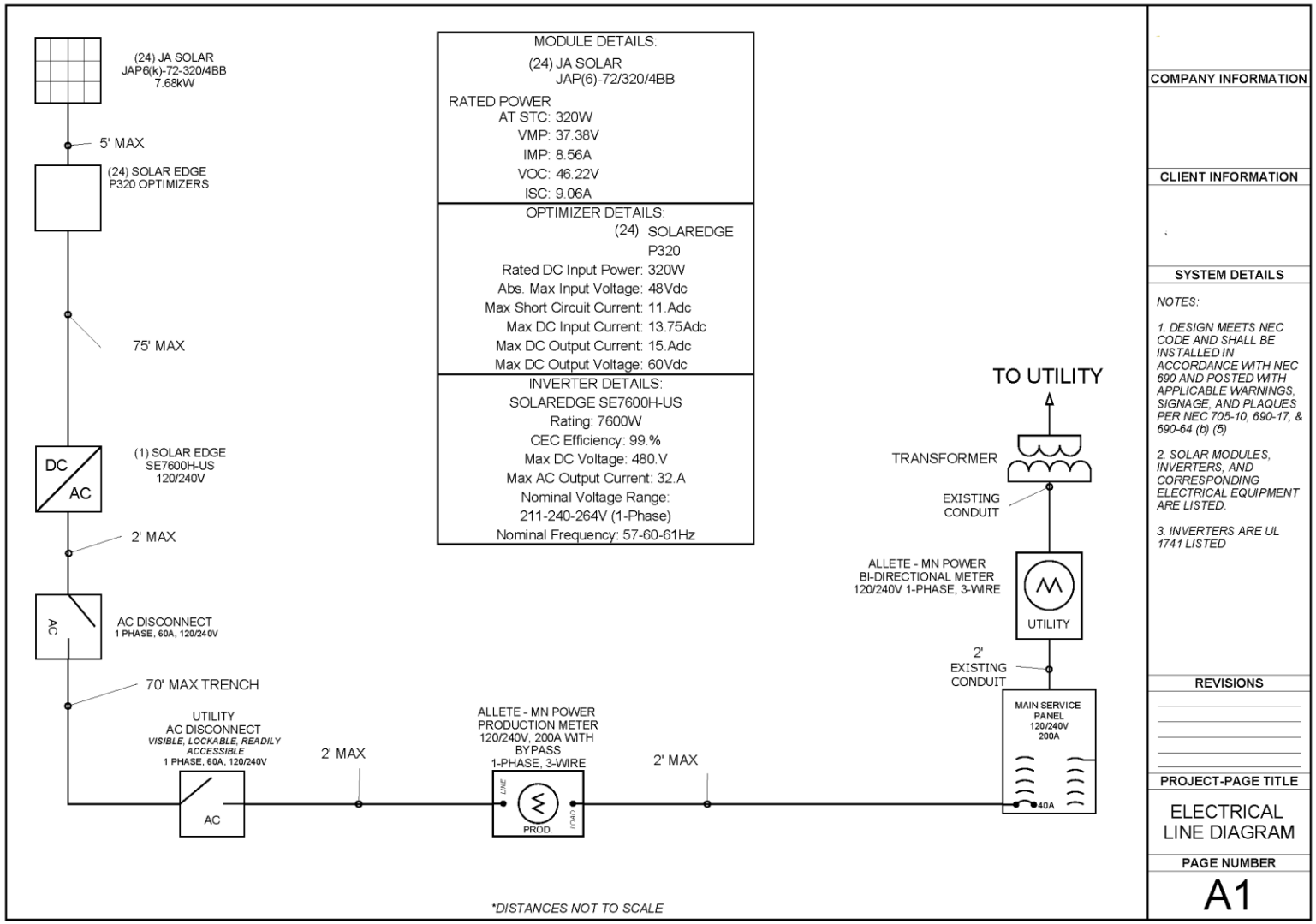
INTERCONNECTION PROCESS- EXAMPLES

- Interconnection fees
  - All– Application fee
  - Commissioning fee- CLP & ECE
  - Grid Access fees- CLP
- Commissioning procedures and expectations

APPLICTICATION PROCESS

- Simplified- 20 kW and less
- Fast Track- > 20 kW to 'larger'
- Study – larger systems with potential system impacts ~250 kW
- Need to submit detailed design plans
  - One line
  - Site Plan
  - Insurance
  - Application fees

SAMPLE SUBMITTALS



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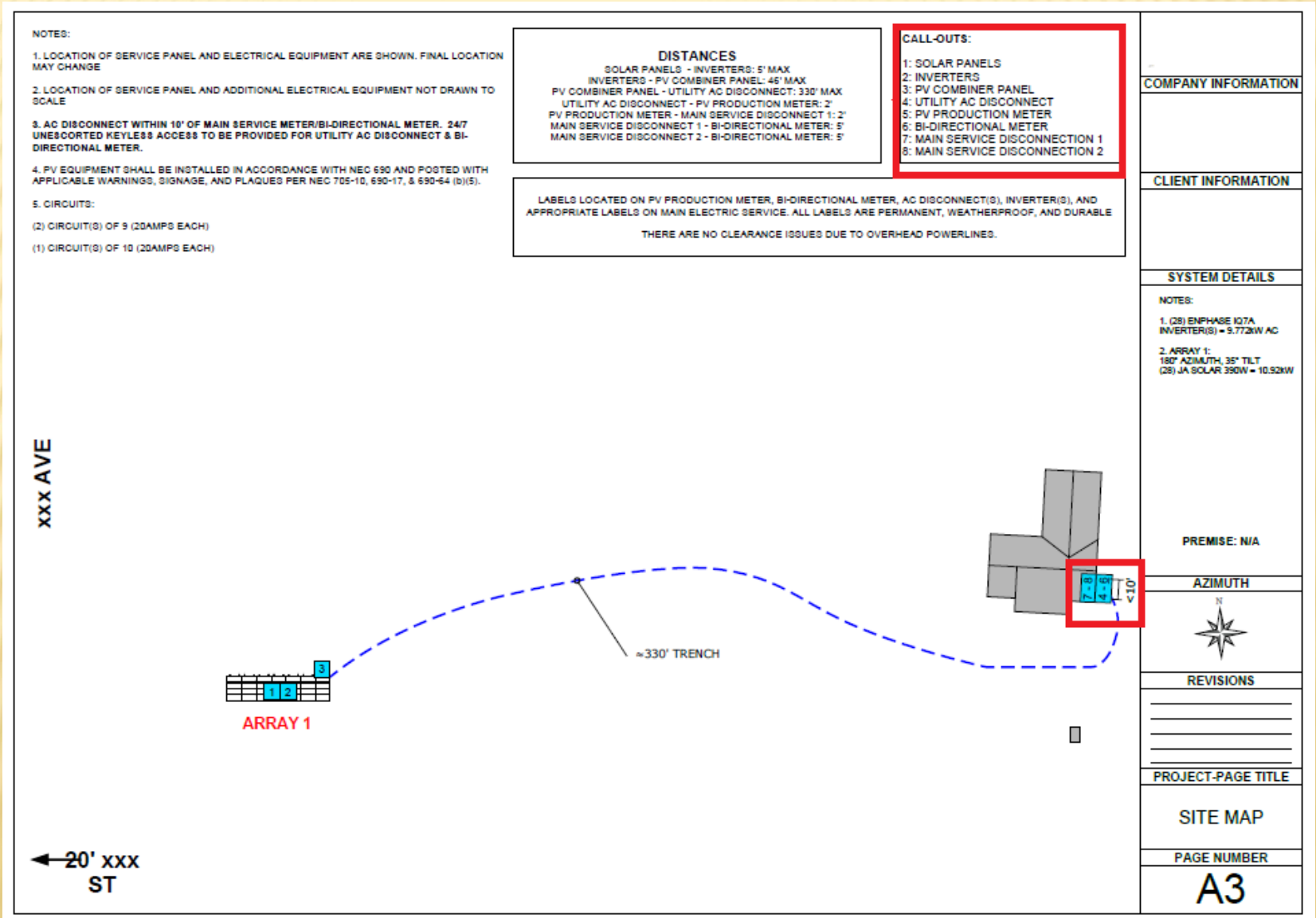


NOTES:

1. LOCATION OF SERVICE PANEL AND ELECTRICAL EQUIPMENT ARE SHOWN. FINAL LOCATION MAY CHANGE

2. LOCATION OF SERVICE PANEL AND ADDITIONAL ELECTRICAL EQUIPMENT NOT DRAWN TO SCALE

3. AC DISCONNECT WITHIN 10' OF MAIN SERVICE METER/BI-DIRECTIONAL METER. 24/7 UNESCORTED KEYLESS ACCESS TO BE PROVIDED FOR UTILITY AC DISCONNECT & BI-DIRECTIONAL METER.

4. PV EQUIPMENT SHALL BE INSTALLED IN ACCORDANCE WITH NEC 690 AND POSTED WITH APPLICABLE WARNINGS, SIGNAGE, AND PLAQUES PER NEC 705-10, 690-17, & 690-64 (b)(5).

5. CIRCUITS:

(2) CIRCUIT(S) OF 9 (20AMPS EACH)

(1) CIRCUIT(S) OF 10 (20AMPS EACH)

DISTANCES

SOLAR PANELS - INVERTERS: 5' MAX
INVERTERS - PV COMBINER PANEL: 46' MAX
PV COMBINER PANEL - UTILITY AC DISCONNECT: 330' MAX
UTILITY AC DISCONNECT - PV PRODUCTION METER: 2'
PV PRODUCTION METER - MAIN SERVICE DISCONNECT 1: 2'
MAIN SERVICE DISCONNECT 1 - BI-DIRECTIONAL METER: 5'
MAIN SERVICE DISCONNECT 2 - BI-DIRECTIONAL METER: 5'

CALL-OUTS:

1: SOLAR PANELS
2: INVERTERS
3: PV COMBINER PANEL
4: UTILITY AC DISCONNECT
5: PV PRODUCTION METER
6: BI-DIRECTIONAL METER
7: MAIN SERVICE DISCONNECTION 1
8: MAIN SERVICE DISCONNECTION 2

LABELS LOCATED ON PV PRODUCTION METER, BI-DIRECTIONAL METER, AC DISCONNECT(S), INVERTER(S), AND APPROPRIATE LABELS ON MAIN ELECTRIC SERVICE. ALL LABELS ARE PERMANENT, WEATHERPROOF, AND DURABLE

THERE ARE NO CLEARANCE ISSUES DUE TO OVERHEAD POWERLINES.

xxx AVE

≈330' TRENCH

ARRAY 1

20' xxx ST

COMPANY INFORMATION

CLIENT INFORMATION

SYSTEM DETAILS

NOTES:

1. (28) ENPHASE IQ7A INVERTER(S) = 9.772kW AC

2. ARRAY 1:
180° AZIMUTH, 35° TILT
(28) JA SOLAR 390W = 10.92kW

PREMISE: N/A

AZIMUTH

N

REVISIONS

PROJECT-PAGE TITLE

SITE MAP

PAGE NUMBER

A3

APPLICATION PROCESS

- Set timeline guildelines
  - Can take up to 4 weeks for simplified
- Study process takes much longer
  - 6 months
- Upgrade requirements may be needed

SO YOU WANT TO GO SOLAR……

- High level expectation for solar arrays in MN:
  - ~$3.20/watt installed
  - About a 10 year payback- very simple
  - Expect about 1100-1200 kWh/kWp/yr
- Selling Solar:
  - Customer goals
  - Longevity in the space (home or business)
  - Realistic expectations

SELLING SOLAR

- Solar design concerns
  - Shade, tilt, azimuth
  - Roof vs. Ground
  - Roof condition
  - Distances to meters/services
- Customer Goals
  - Longevity
  - Utility costs
  - Ethical concerns
- Incentives and Financing

FEDERAL TAX CREDIT

- IRA-Inflation Reduction Act 2022
  - 30% of the cost of installed systems through 2032
  - Accelerated depreciation (MACRS) for commercial
  - Storage systems also have stand alone ITC treatment.
  - Non-Profit and Governmental- direct pay

SOLARSENSE PROGRAM

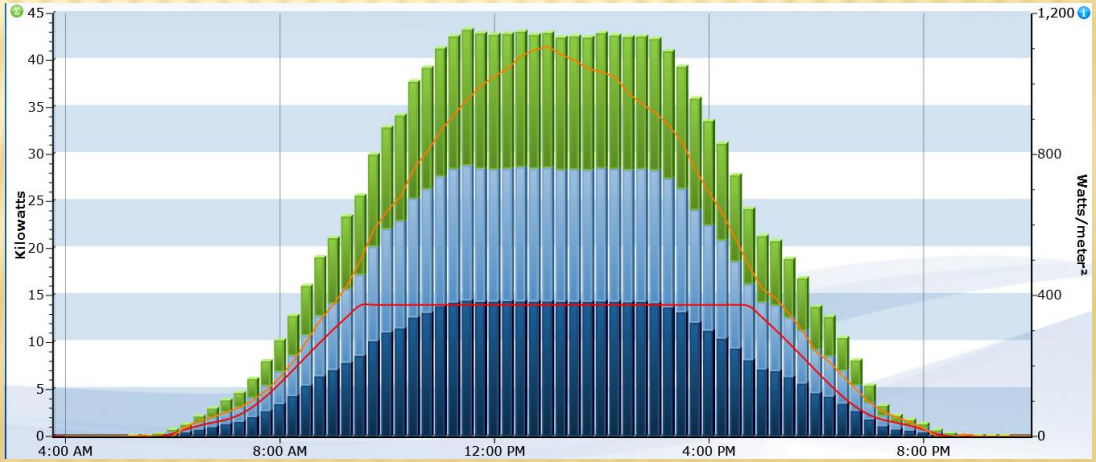
- Small Rebate dollar pool available to retail customers of MP
- $5000 cap
- ~10% of cost
- Currently approved through 2024
- March 1-3 application period

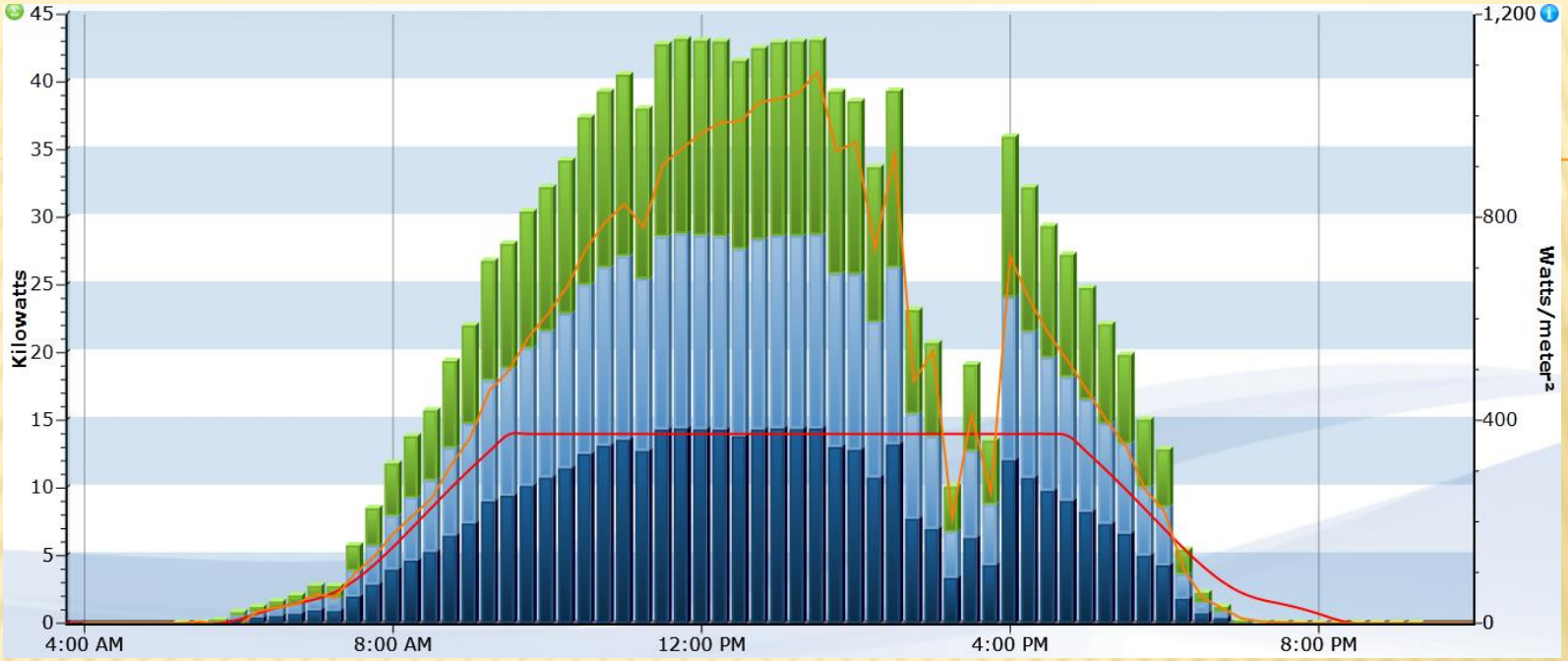
XCEL SOLAR*REWARDS

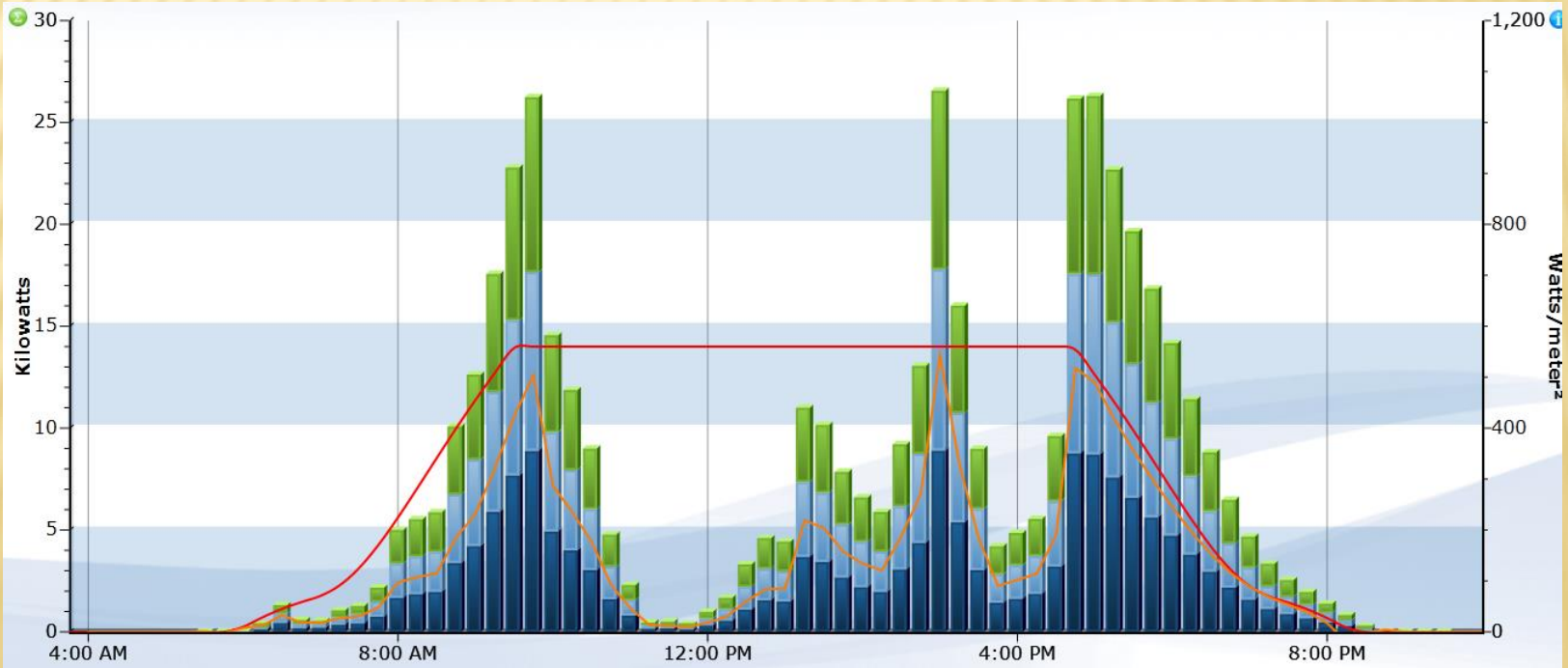
- Production based incentive: payments based on production of systems
- 10 years of annual payments
- $0.02/kWh Residential
- Income Qualified program: +$2/watt
- Non Prof/Gov: $0.015 + $1/watt
- Multi-Fam: + $0.50/watt

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

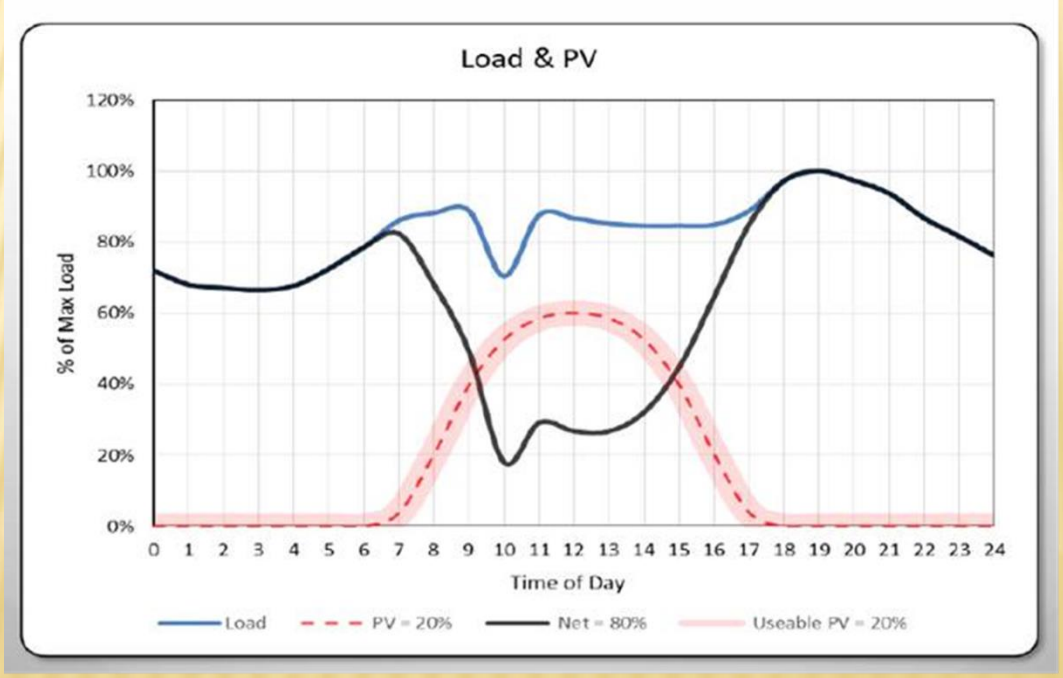



45
40
35
30
25
20
15
10
5
0
Kilowatts
1,200
800
400
0
Watts/meter²
4:00 AM
8:00 AM
12:00 PM
4:00 PM
8:00 PM


30
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

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.

NEXUS OF TECH- EVS - STORAGE

THANK YOU!

- Questions and Answers

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