Brown to Green Solar Field Development

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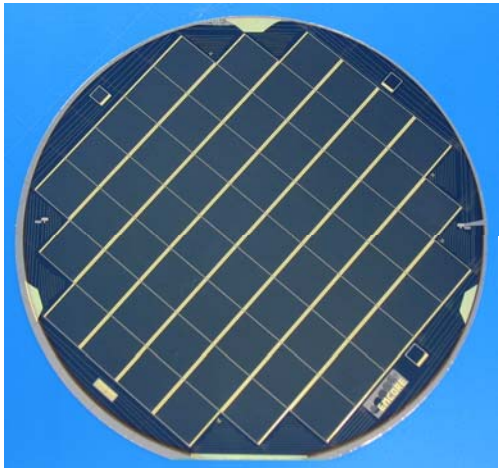
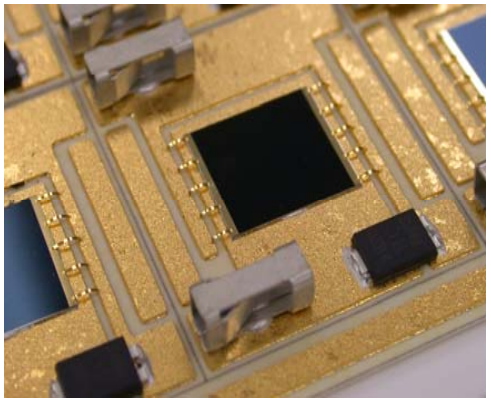
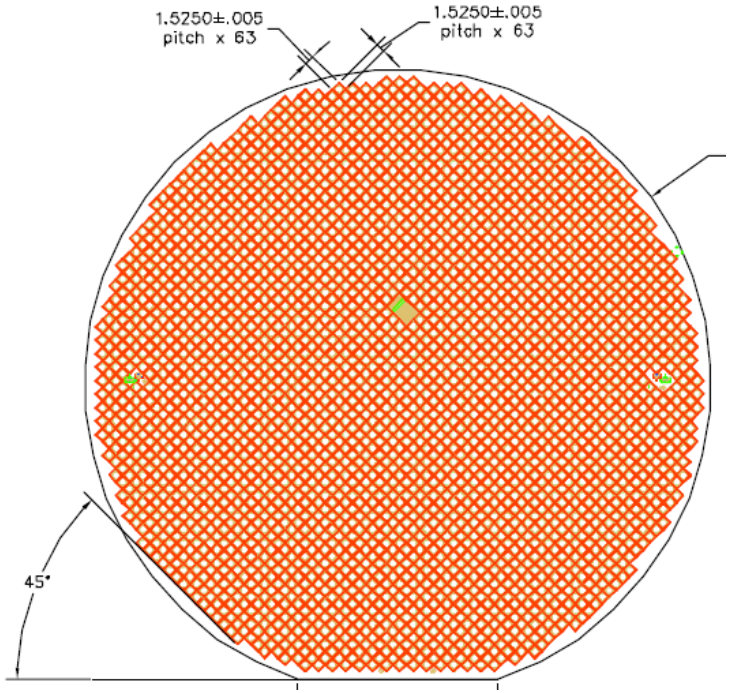
Overview

1. Emcore “Requisite” Overview
2. Solar Technologies
   - Solar Resources in the US
   - What’s Available Today
   - CPV 101
3. Brown to Green Solar Development
   - How to Start
   - Challenges
   - Benefits







The Requisite Company Overview (Short, I promise)

Emcore Corporation Overview

- Emcore Corporation is a U.S.-based, NASDAQ-listed manufacturer of Solar and Fiber Optical products based on compound semiconductor technology
- Founded in 1984 by scientists from AT&T Bell Labs - Initial business was to design and manufacture MOCVD semiconductor equipment
- Revenue in FY07 and FY08: $170M and $240M, respectively
- Manufacturing facilities in Albuquerque, New Mexico; Alhambra, California and Langfang City, China

Space	CPV Concentrated PV
Space Solar Cells Space Solar Panels 	 –CPV Cells –CPV Receivers –CPV Modules –CPV Systems

Emcore Solar

Broadband	Data/Telecom
CATV Tx/Rx FTTx Tx, PON TRx RF over fiber links Fiber-optic gyro Video Transport 	 DataCom Component Telecom Component 10 GE TRx (LX4, CX4) Parallel Optical TRx

Emcore Fiber Optics

Emcore PROPRIETARY INFORMATION

Emcore's Albuquerque Operations

- **Started in 1998 with acquisition of MODE, a Sandia spin-off**
- **The 1st tenant of SSTP**
  - 1st facility opened in October 1998
- **Further expansion**
  - Expansion on 1st building in 99
  - 2nd facility opened in July 2000
  - Expansion on Bldg 1 again in 2006
- **State-of-the-art facility of 180,000 ft^2 for clean-room and test/assembly operations**
- **Close partnership with SNL**
  - Three product lines all built on Sandia's technology
  - Established two new BUs
    - Emcore Photovoltaics, 1998
    - Emcore Fiber Optics, 2000
    - Emcore Solar Power, 2006
- **Total investment in Albuquerque: >$200M**
- **Moved the Headquarters to Albuquerque in 2006**

We Came From Space…….

Markets

- Satellite Power Systems
- Terrestrial CPV Power Systems

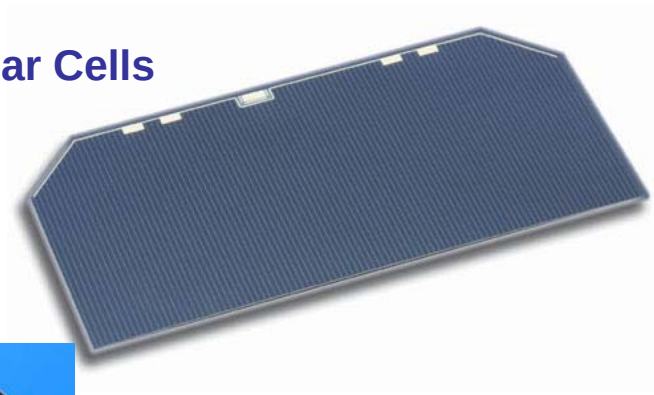
Major Customers

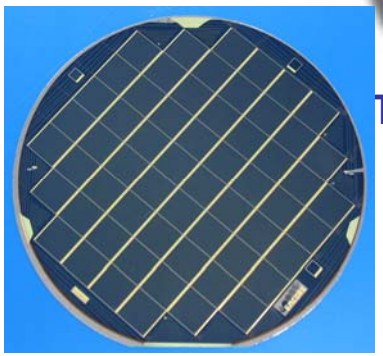
- Space Systems/Loral, Boeing, Lockheed Martin, Northrop Grumman, Astrium
- Working with all Major CPV System Integrators

Products

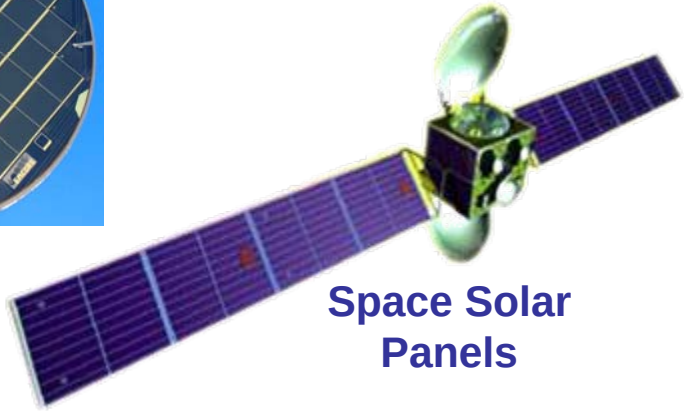
- High Reliability Space Power Components Using 28.5% Efficiency Solar Cells
  - Fully Integrated Solar Panels
  - Covered Interconnected Cells
- Terrestrial CPV Products Based on Multi-junction Solar Cells
  - CPV Receivers – Customized or Standard Design
  - Bare Solar Cells

Space Solar Cells

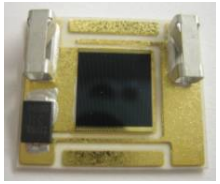




Terrestrial Solar Cells

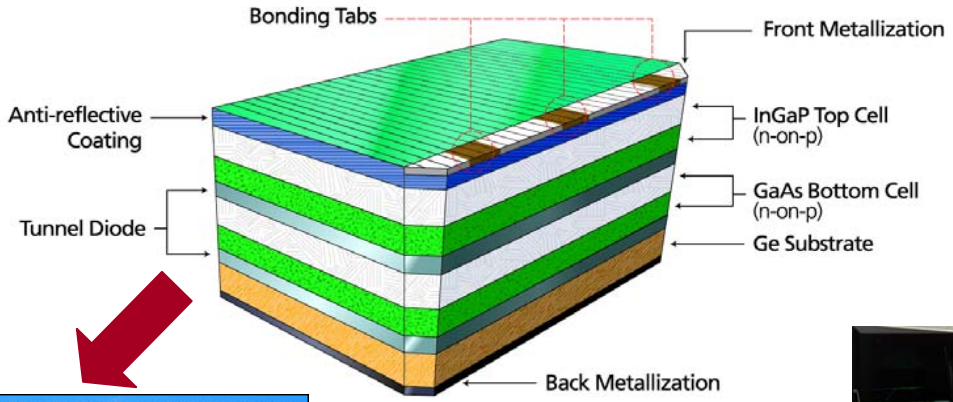


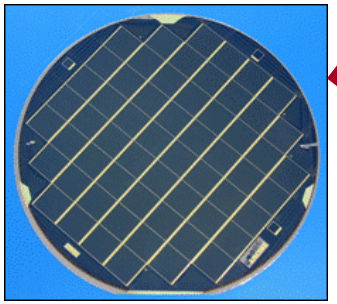
Space Solar Panels

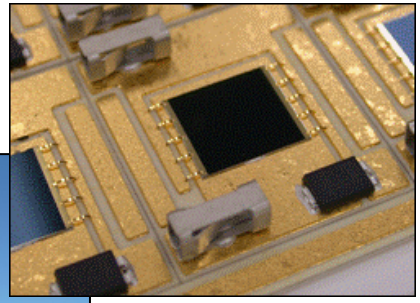


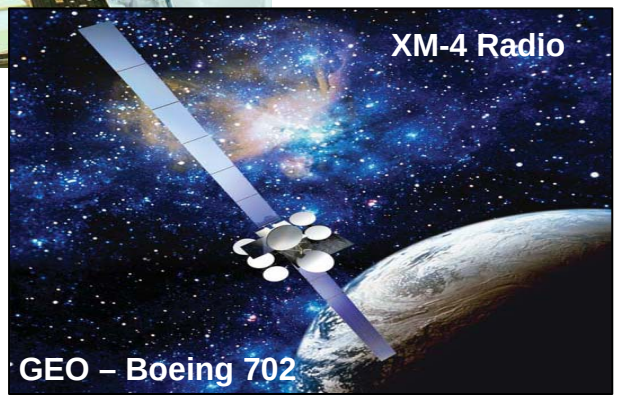
Terrestrial Receivers

EMCORE Solar Technology & Applications







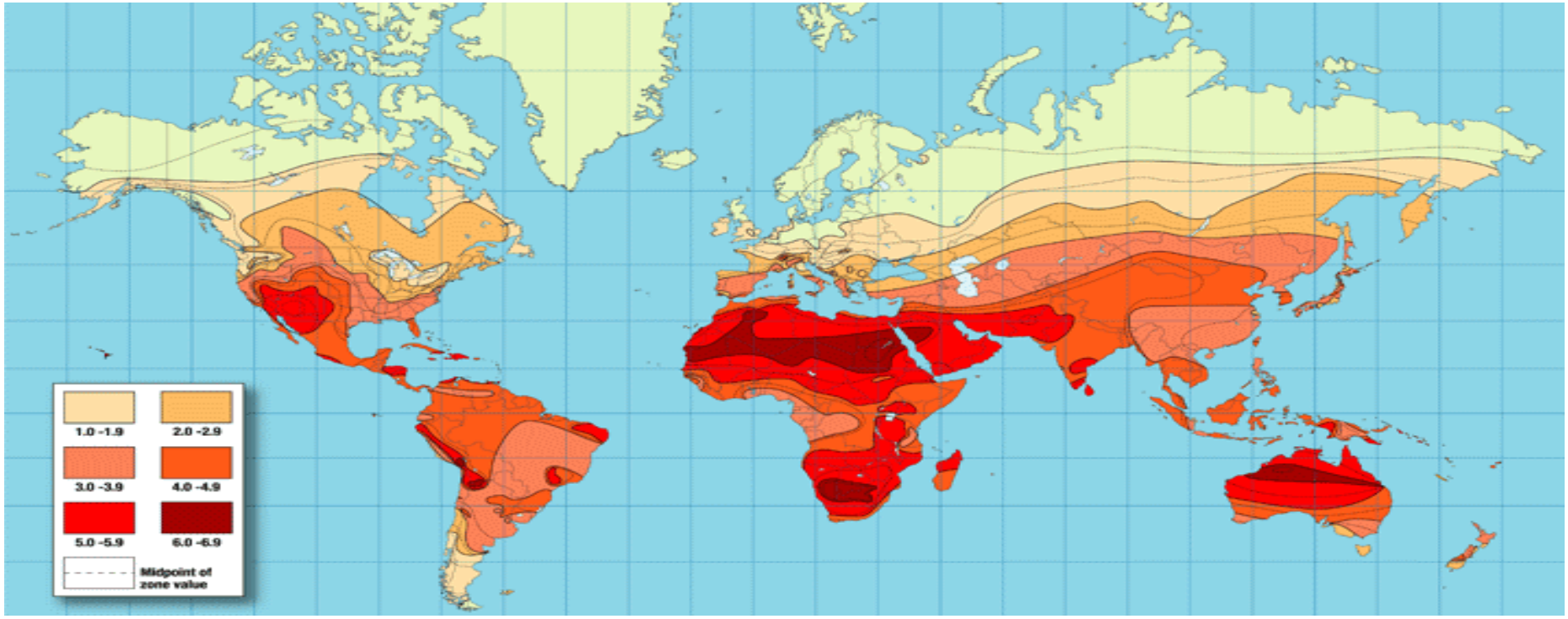


Solar 101
And How CPV Works

Solar Demand Drivers

- **High and volatile energy prices and need for energy security**
  - Fossil fuel prices and consumption are at all-time highs and fluctuating dramatically
  - World electricity use expected to double by 2030
  - Increased focus of energy policy on national security
- **Global demand for renewable energy**
  - Solar featured prominently in international and U.S. energy policies
  - U.S. funded ITC, while Europe provides feed-in tariffs
- **Renewable Energy can provide large-scale market needs**
  - Renewable energy can provide secure, stable, economically sound, long-term energy solutions in the face of rising costs
  - Investment in Renewable Energy is an investment in US infrastructure
  - Renewable Energy costs are higher than fossil fuel today, but Renewable Energy offers a lower cost of ownership in cost and carbon footprint
- **Lower cost, higher-efficiency technologies are better suited for commercial and utility markets**
- **Solar and Wind Complement, not Compete – They tend to peak at different times so work well together. Both are needed.**

World Wide Solar Resources

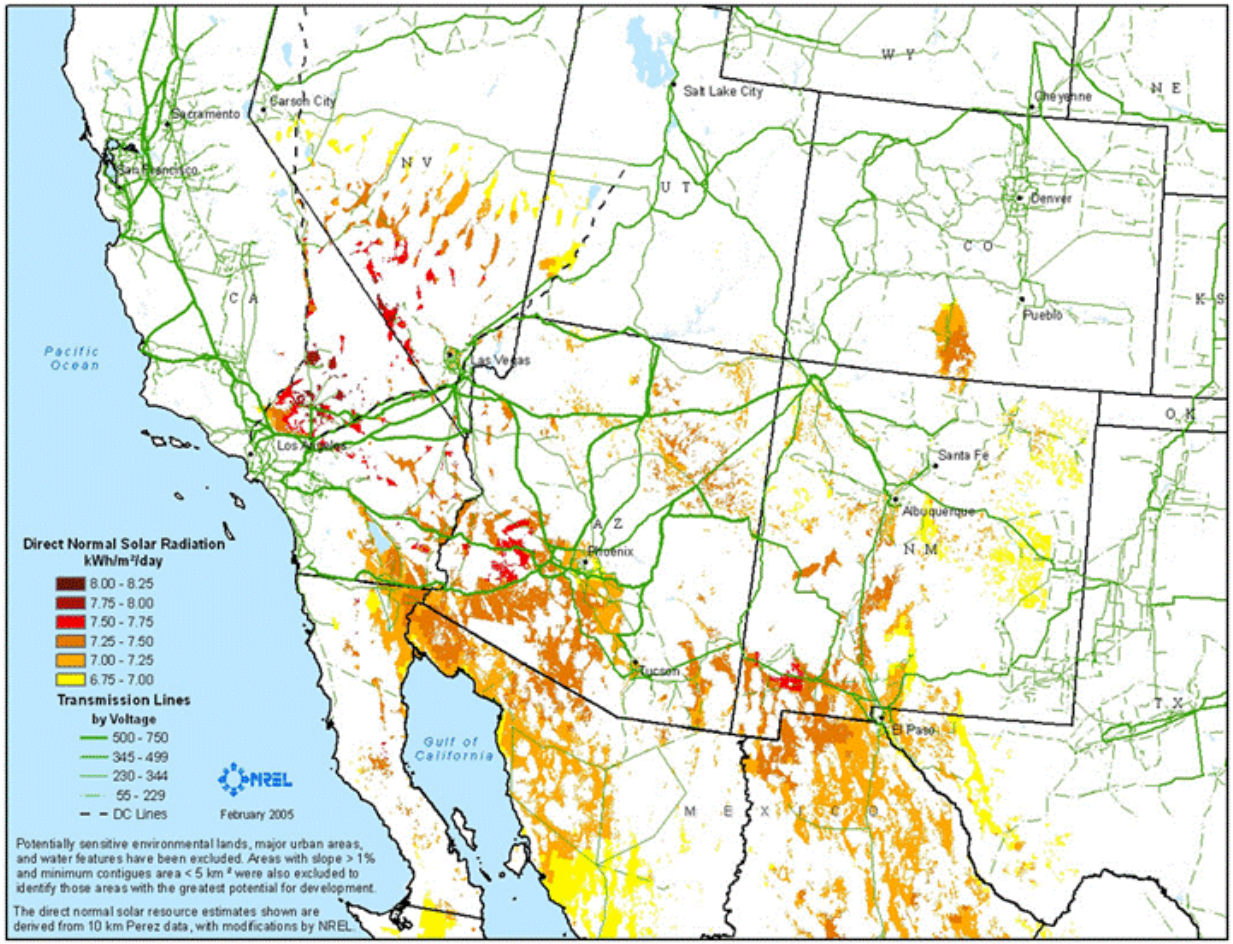


- **Solar can work in almost any region, it works better in regions with more sun…….restatement of the obvious but**
- **Germany has more solar installed than any other country - 5GW, and one of the poorest solar resources – Korea, Ontario also have aggressive programs**
- **The US is woefully behind – the largest PV project is 12MW in Nellis AFB**

Solar Resource in the Southwest US

Bottom Line, The Southwest US has:

- **6.9 TW of available solar resource capacity**
- **4 times current annual U.S. consumption for electrical use**



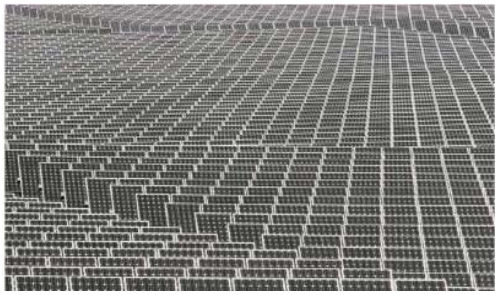
Solar Comes In all Shapes and Sizes

Solar Technology

CPV

Thin Film

Flat Plate C-Si



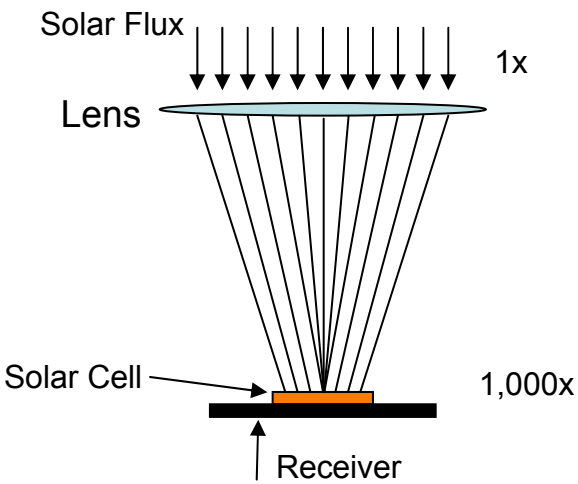
Solar Thermal

- **CPV is the least well known of the solar technologies**
- **Each technology has strengths and weaknesses and has a place in the market**
- **Choose the best technology for the location and application**

CPV Overview

Utilizes advanced solar cells to provide the most cost effective solution

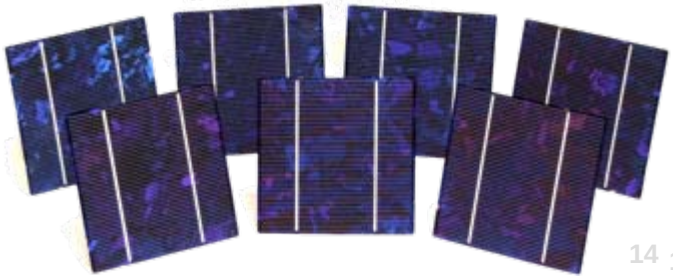
- **Lens concentrates solar flux from 500 to 1,000 times normal irradiance**
- **Area of solar cell is then reduced by a factor of 500 to 1,000 compared to a full coverage**
- **Conversion efficiency improves under concentrated illumination**
  - 38% cell efficiency in production
  - 40% cell efficiency recently achieved in testing
- **CPV is similar to PV – Water rights are not required for electricity production. Minimal water required for cleaning.**



One 1 cm^2 Triple Junction CPV

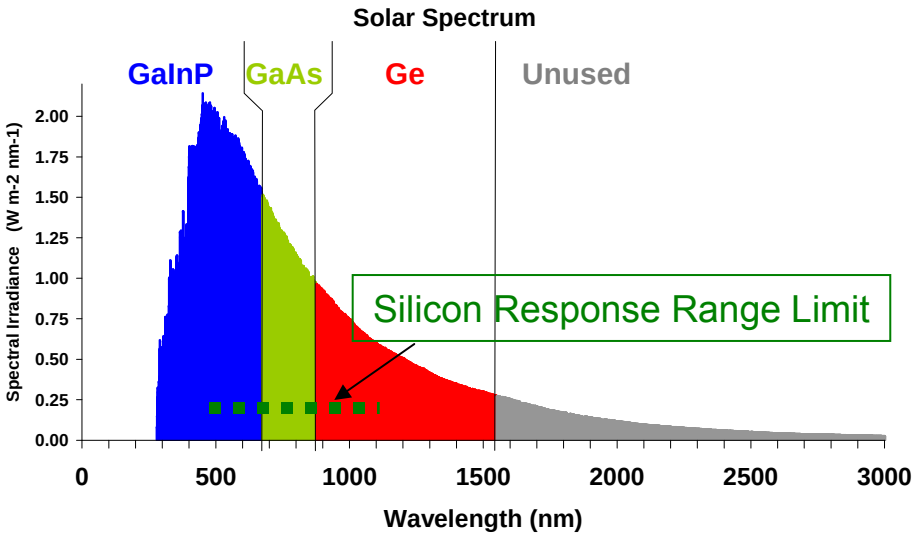
Produces As Much Power As

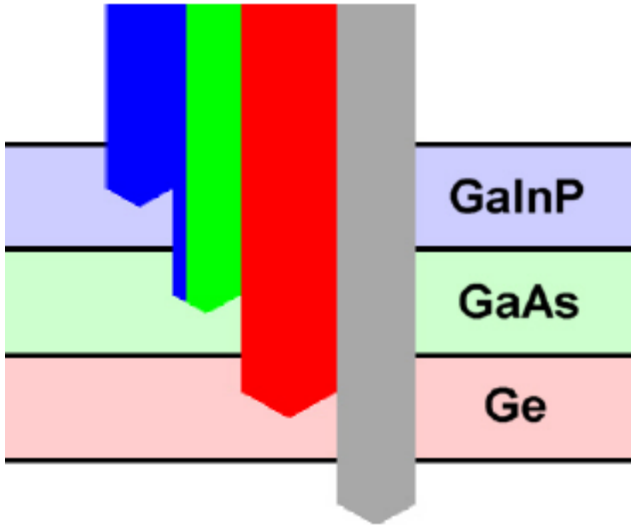
Fourteen 5" Silicon Cells



CPV Triple Junction Solar Cells
Replacing Silicon Based Applications

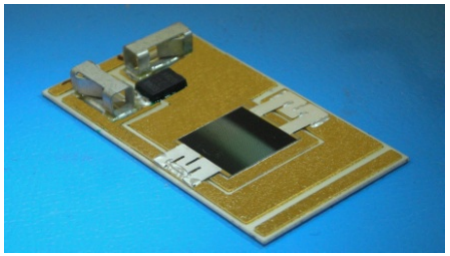
- **Emcore's Technology Employs Three Compound Semiconductor Solar Cells in Series**
  - Each cell is tuned to absorb a different color of light
- **By Converting More Sunlight into Electricity, Emcore's Solar Cells Operate at Higher Efficiency**
- **III-V Multi-Junction Technology Improvements Promise Still Higher Future Performance**



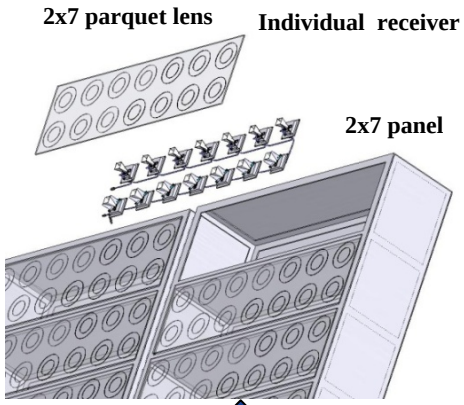


CPV System Assembly

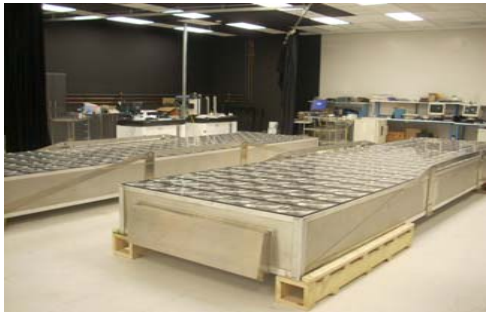
Multi-Junction Cell on Receiver



2x7 Panel

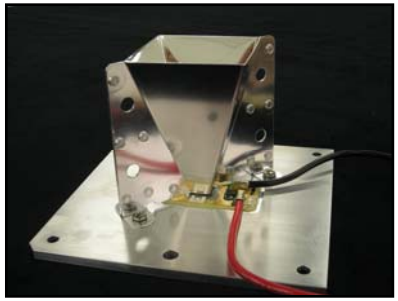


Full-Size Module



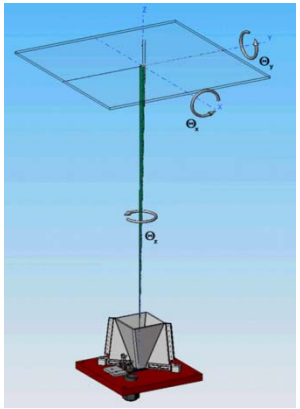
182 Cells – 2500 Watts
Minimum field replaceable unit

Cell & Receiver Assembly



Cell, Heat sink, Secondary Optic, Cabling

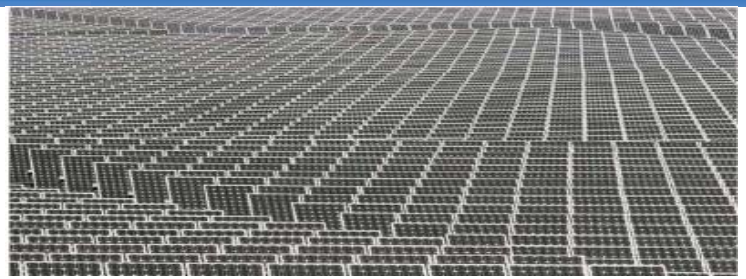
Optics Aligned to Receiver Assembly



CPV System

10 Modules
Continuous 2-Axis Sun-Tracker
25 kW

CPV Systems vs. Flat Plate C-Si Systems



Module Conversion Efficiency:	25% - 32% (Cell Efficiency of 38-40%)	12% - 18%
Capex Cost $/W:	$0.32	$2.00 - $2.50
LCOE $/kWh[1]:	$0.10	$0.12
Competitive Advantages:	▲ Lowest LCOE will accelerate grid-parity ▲ Leading cell efficiencies (38-40%) ▲ Concentration significantly lowers cost and use of PV materials ▲ Higher electricity generation in optimal DNI conditions ▲ No dependence on high-cost polysilicon ▲ Clear roadmap to continued cost and efficiency improvement	▲ Predominant PV technology today ▲ Proven reliability and warranty history ▲ Most competitive for residential and small- to medium-scale commercial markets
Competitive Obstacles:	▼ Minimal market acceptance to date ▼ Limited industry CPV capacity today ▼ Limited history of on-grid reliability	▼ Highest-cost solar module (~$3.20-$3.50/W) today ▼ Current polysilicon shortage and strong demand preventing module price decline

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CPV Systems vs. A-Si Thin Film Systems

Module Conversion Efficiency:	25% - 32% (Cell Efficiency of 38-40%)	6% (a-Si) - 12% (CdTe)
Capex Cost $/W:	$0.32	$0.90 (CdTe) - $2.00 (a-Si)
LCOE $/kWh[1]:	$0.10	$0.13 (CdTe) - $0.15 (a-Si)
Competitive Advantages:	▲ Lowest LCOE will accelerate grid-parity ▲ Leading cell efficiencies (38-40%) ▲ Easy to scale up production – lowest per MW capex cost ▲ Concentration significantly lowers cost and use of PV materials ▲ Dual-axis tracking improves energy production by 20%-30% ▲ Clear roadmap to continued cost and efficiency improvement	▲ Lowest-cost product today ▲ Easy to scale-up production ▲ Effective in diffuse light conditions ▲ Flexible substrate broadens market opportunity to BIPV
Competitive Obstacles:	▼ Minimal market acceptance to date ▼ Limited industry CPV capacity today ▼ Most effective in high Direct Normal Irradiance (DNI) environments ▼ Limited history of on-grid reliability	▼ Low efficiency (as low as 6% for a-Si) ▼ Low energy density → low land efficiency, high balance of system costs and cost prohibitive for trackers ▼ Environmental concerns with some materials (CdTe) ▼ Complicated production process has slowed commercialization of next-generation thin film technologies (CIGS)

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CPV Systems vs. Solar Thermal Systems

Installed Cost $/W:	$4.00	$3.50 - $4.00
LCOE $/kWh[(1)(2)]:	$0.10	$0.08 - $0.11
Competitive Advantages:	▲ Lowest LCOE will accelerate grid-parity ▲ Leading cell efficiencies (38%) ▲ Concentration significantly lowers cost and use of PV materials ▲ Dual-axis tracking improves energy production by 20%-30% ▲ Clear roadmap to continued cost and efficiency improvement ▲ Well-suited for distributed and utility-scale generation applications	▲ Inexpensive – no dependence on high-cost polysilicon or other photovoltaic materials ▲ Favorable economies of scale given size of projects ▲ Potential to store and dispatch energy
Competitive Obstacles:	▼ Minimal market acceptance to date ▼ Limited industry CPV capacity today ▼ Limited history of on-grid reliability	▼ Minimal market acceptance to date ▼ Potentially significant water requirements ▼ Large load fluctuation and interconnect concerns to transmission line ▼ Large-scale facility siting issues ▼ Long deployment lead time ▼ Slow to reach peak output in intermittent sun conditions ▼ Limited versatility – best suited for large-utility-scale

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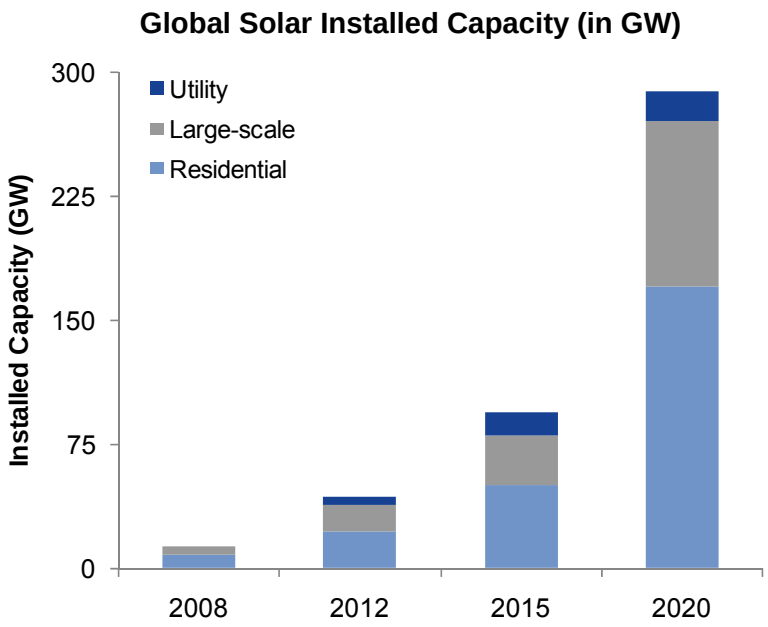
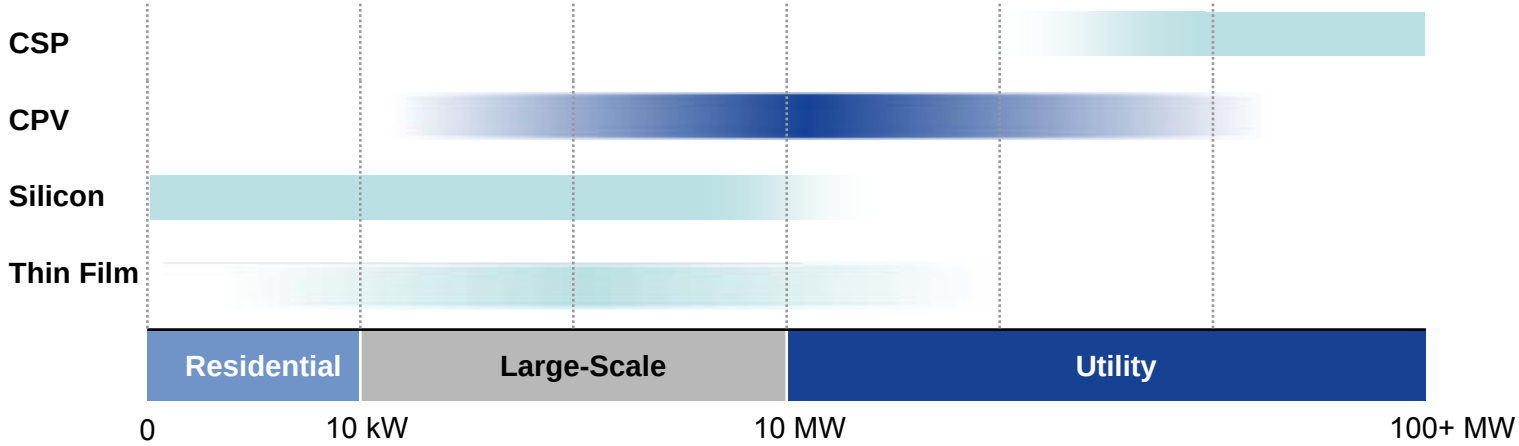
CPV Advantages

- Uses highest efficiency solar cell (III-V Triple Junction) allowing for higher watt output per cm2 (about 30w/cm2)
- Uses 1000 times less semiconductor material as traditional flat plate systems
- Small amount of semiconductor material allows for aggressive system pricing and ease of recycling
- III-V solar cells perform better under hot environmental conditions than flat panel systems
- No water needed for operation
- No significant earth movement or land-leveling for installation
- Modularity providing flexibility of application and increased reliability
- High operational reliability due to on-line monitoring, control, and diagnostic access
- Reduced capital expenditure compared to flat panel systems
- Full dual axis tracking of the sun from early morning to late evening
- No odor, noise, or greenhouse gases emitted from the solar plant

Large-Scale and Utility-Scale End Markets



- Global large- and utility-scale solar installations projected to grow to ~120 GW by 2020
- Technologies will serve specific end market applications based on system scale
- CPV will serve broad end markets – from large-scale commercial to utility-scale applications
- CPV will benefit from trend to larger system installations
  - Scale permits improved economics
  - CPV's low capex pet watt an important advantage as growth accelerates – minimizes financing and capital risk



Source: Prometheus Institute

The Project(s)

Developing a Renewable Energy Project n 14 Easy Steps…

1. Identify site and suitable renewable technology
2. Identify transmission interconnection point
3. Identify potential power buyers
4. Get a bank to agree to finance the project (very difficult)
5. Form a corporation to operate the project
6. Secure the site
    - 6.1 Approval from Land Owner
    - 6.2 Site Survey
    - 6.3 Environmental Clearances
    - 6.4 Site Engineering (is the site suitable for the project?)
    - 6.5 Lease
7. Sign a Power Purchase Agreement with the customer
8. Enter into a partnership with the bank to build the project
9. Hire construction company
10. Grade and prepare the site
11. Install generating equipment (solar panels)
12. Interconnect with power grid
    1. Interconnection Application
13. Provide power to customer
14. Wait for the money to arrive

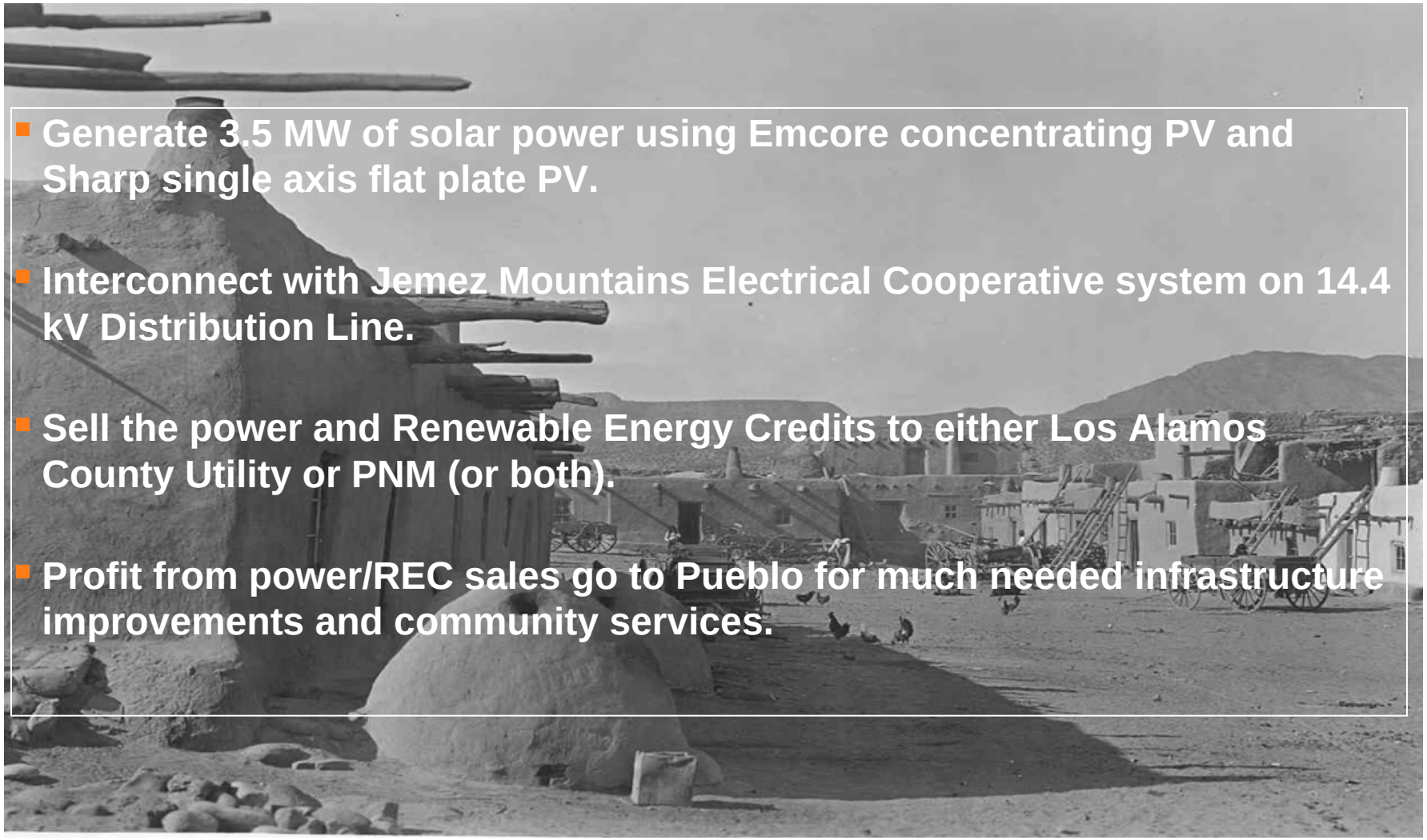
Additional Challenges on Brown to Green

- **Financing**
  - Financing is hard enough in today's environment, it gets a second, third, and fourth look on "marginal lands"
- **Methane/Gas Seepage**
  - The first question everyone asks…..
  - Glass half empty – Won't that cause an explosion, cause suffocation, poisonous…
  - Glass half full – Can you harness the methane to produce power
- **Settling**
  - The most important question – is the landfill stable enough to support solar panels
  - The answer can be made to be yes on almost any site – but can it be profitable
- **Hazardous Disturbance**
  - How can you ensure that construction won't be detrimental
- **Soil composition**
  - Related to Settling, but need additional core samples. And may have to change the design of the structure

Benefits of Brown to Green

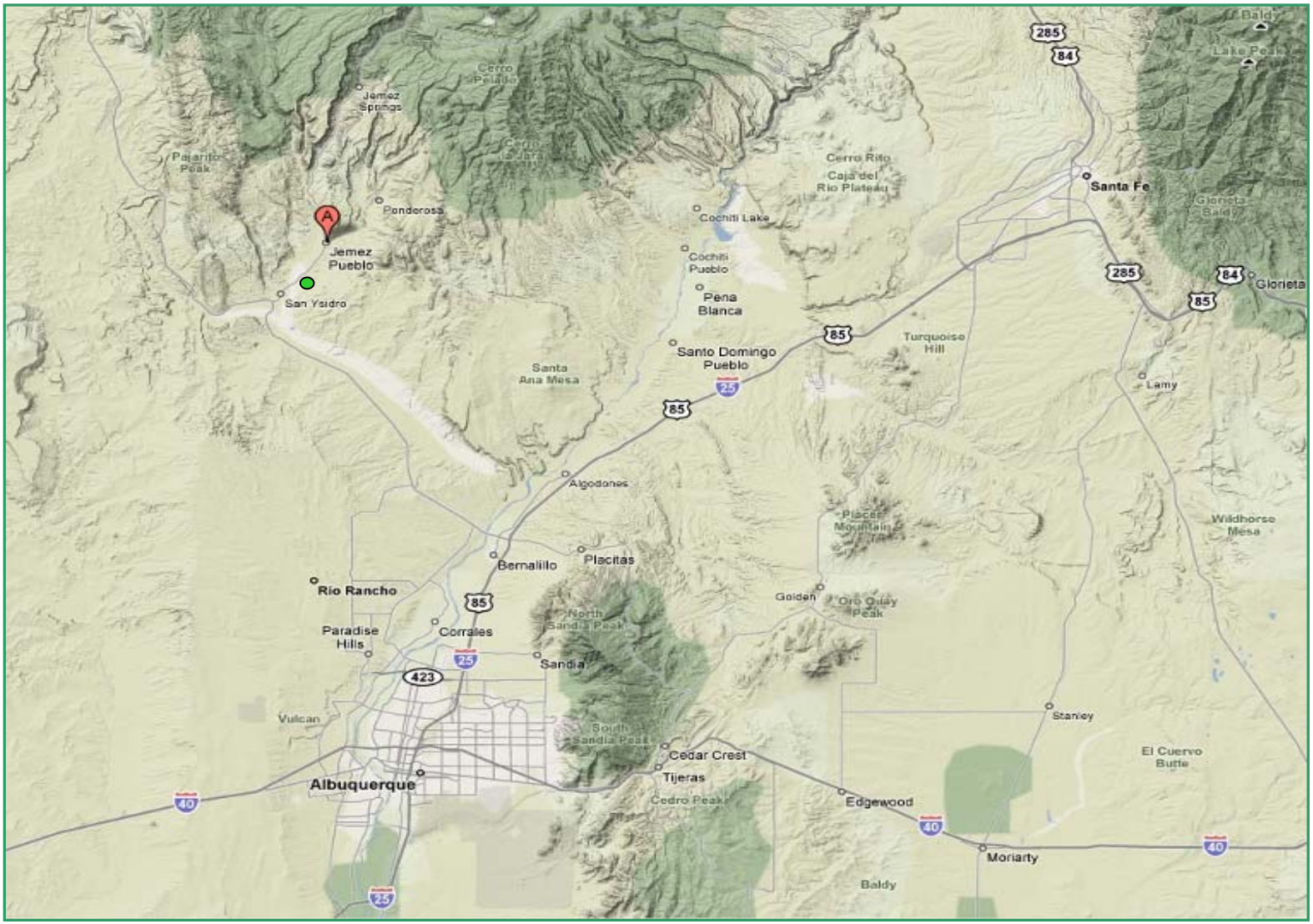
- **Lot's of Help and Support**
  - It's hard not to support a Brown to Green conversion site
  - Support from City, State, Federal agencies, Elected officials
  - Private Industry - Engineering firms are eager to help and support
- **Available Land**
  - There is land available that would not be available if it were not a Brown field
  - Brown land tends to be more affordable
  - Flexibility on zoning and land use
  - Often close to utilities
- **Additional Funding Sources**
  - Still exploring all of the options – but resources are available that are not on private lands.
- **It's a feel good**
  - Renewable energy on land that was previously underperforming

Jemez Project



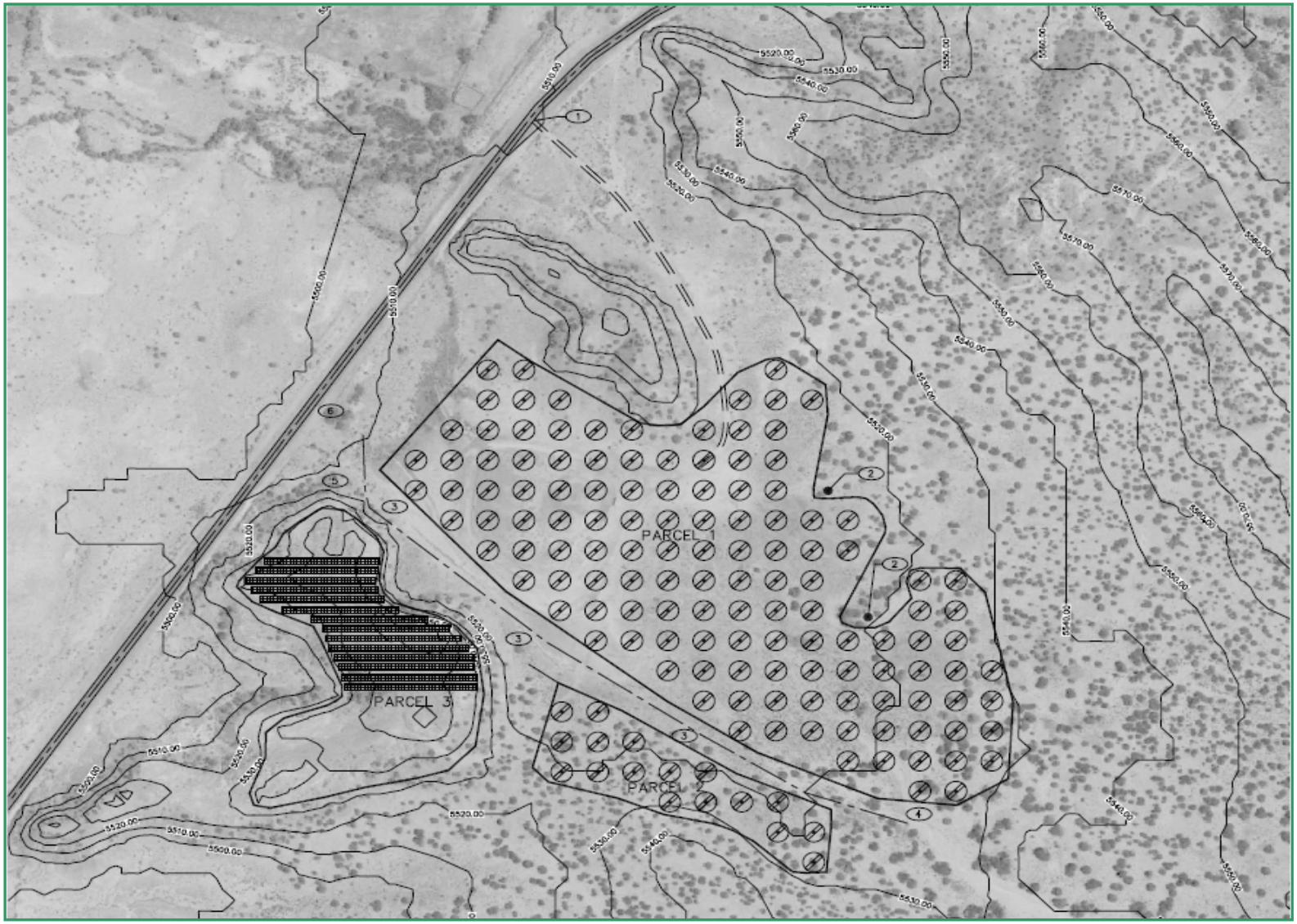
- Generate 3.5 MW of solar power using Emcore concentrating PV and Sharp single axis flat plate PV.
- Interconnect with Jemez Mountains Electrical Cooperative system on 14.4 kV Distribution Line.
- Sell the power and Renewable Energy Credits to either Los Alamos County Utility or PNM (or both).
- Profit from power/REC sales go to Pueblo for much needed infrastructure improvements and community services.

Jemez Project



Vicinity Map

Jemez Project – Site Layout



Proposed 30 acres of buildable area.

Jemez Project – Human Eye View

Looking northeast from atop the mesita across main portion of solar site.

A Perfect Location for "Pilot Deployment"

75 acres owned by State Land Office in close proximity of Sandia Lab/base, SSTP, PNM Substation & Emcore

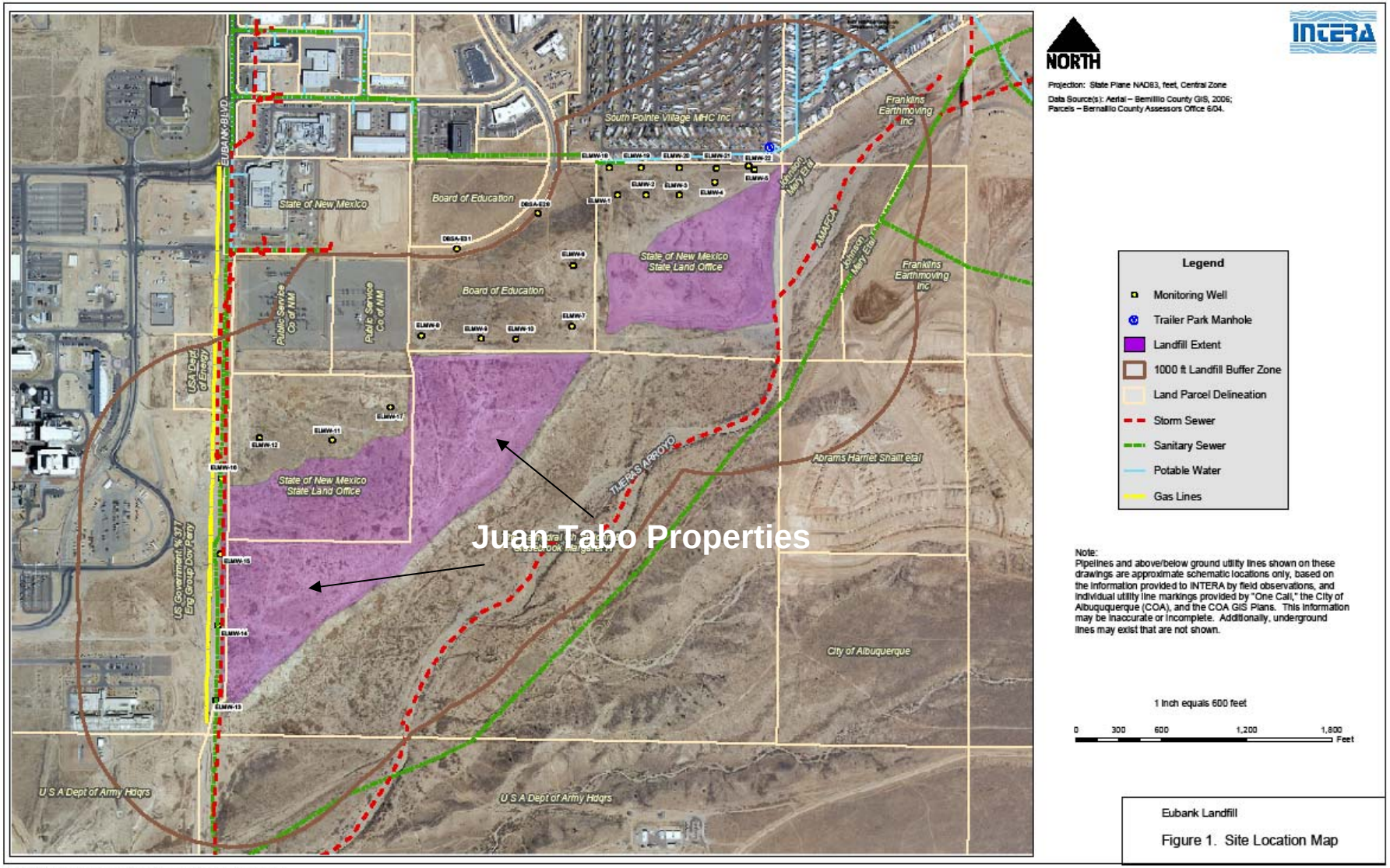
Sandia Science and Technology Park Site
Land Status

- **12MW on 75 acres**
  - Capacity is limited by easements on the land, the initial RFP had the site at 14MW
- **Support from City, State and Federal agencies to use this site**
  - Project is a brown field conversion- formally a landfill, closed in 1970s
  - The land Falls within Sandia Science and Technology Park (SS&TP) boundaries, SSTP has approved this use of the land for Emcore CPV
  - Extensive monitoring and environmental assessment has already been completed by the City of Albuquerque via Intera due to the brown field status of the land
  - A Geo-tech survey was completed ~10 years ago, but will have to be updated
- **Land owned by NM State Land Office, Emcore has signed a LOI for the land, State has agreed to provide Right of Access to finish site evaluation and update the geo-tech work**
  - Currently in discussions with Juan Tabo Properties to secure more land for future expansion. (See maps in coming slides)
- **Emcore has discussed with PNM the possibility of encroachment onto PNM's easements. Site design will accommodate PNM's need to maintain safety and access for line maintenance**

Sandia Science and Technology Park Site Environmental Review

- **Environmental Concerns for Brown Field Sites**
  - Gas- Monitoring wells in place, studies show that levels of methane are not hazardous. No trace of gases evident on the surface.
  - Peak gas was found in 1985 and has been declining ever since.
  - Certificates- Site has received Certificate of Completion for Voluntary Remediation Program. Site conditions meet applicable standards for Voluntary Remediation Program (VRP).
  - Geo-tech studies have been completed for the site by Vinyard and Associates. Emcore will design array foundations in accordance with landfill geo-tech conditions.
- **Intera – Joe Tracy, Jim Joseph, Suzanne Busch from City of ABQ**
  - Intera has been contracted by the city of ABQ to study the landfill
    - Believes solar to be well suited for construction on this landfill do to light weight of Emcore structures
    - Intera does not believe the site contains significant amounts of harmful gas to warrant remediation
    - Do not believe additional soil or compaction is necessary or desirable

Sandia Science and Technology Park Site
Landfill Boundaries



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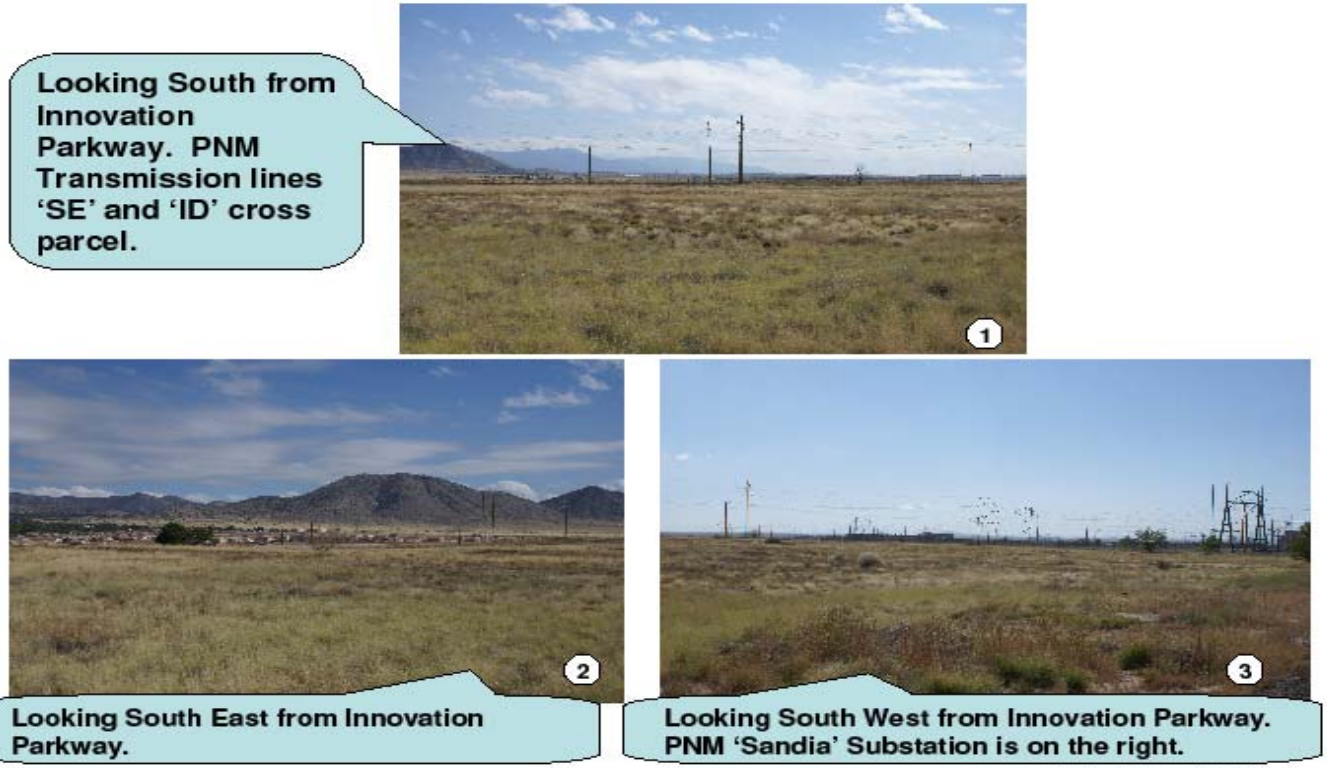
Sandia Science and Technology Park Site Ground Level

- **Land has no major obstructions or slopes, minimal civil work required for site preparation.**
- **Emcore CPV is ideal for this site as minimum impact to the land is made.**
  - Additional fill or land leveling not required

Sandia S & T Park Solar Site



Photos by Emcore 10-2009
Form C3

CPV Array Layout

- **Northeast parcel**

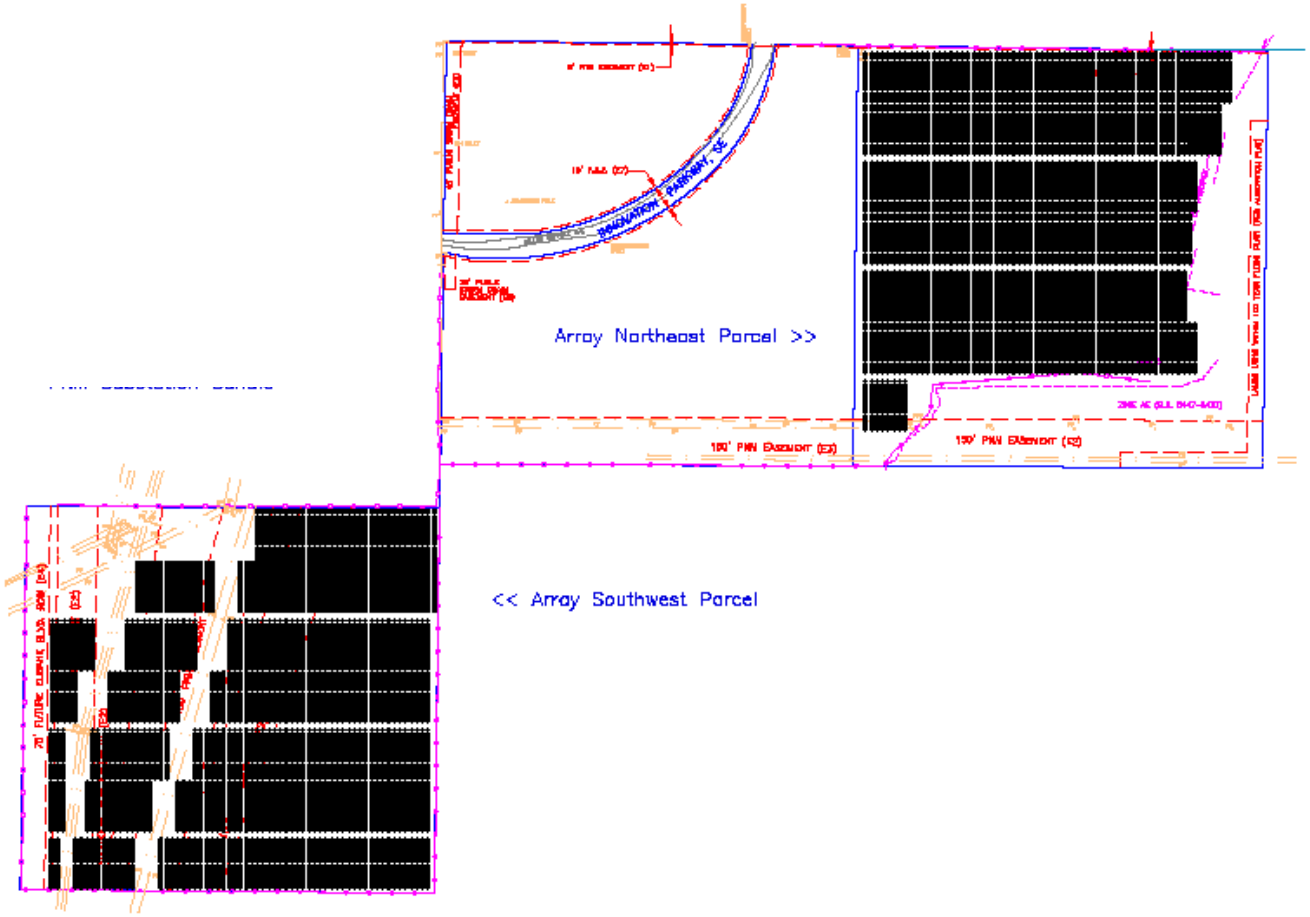
369 arrays

5,904 kW

- **Southwest parcel**

373 arrays

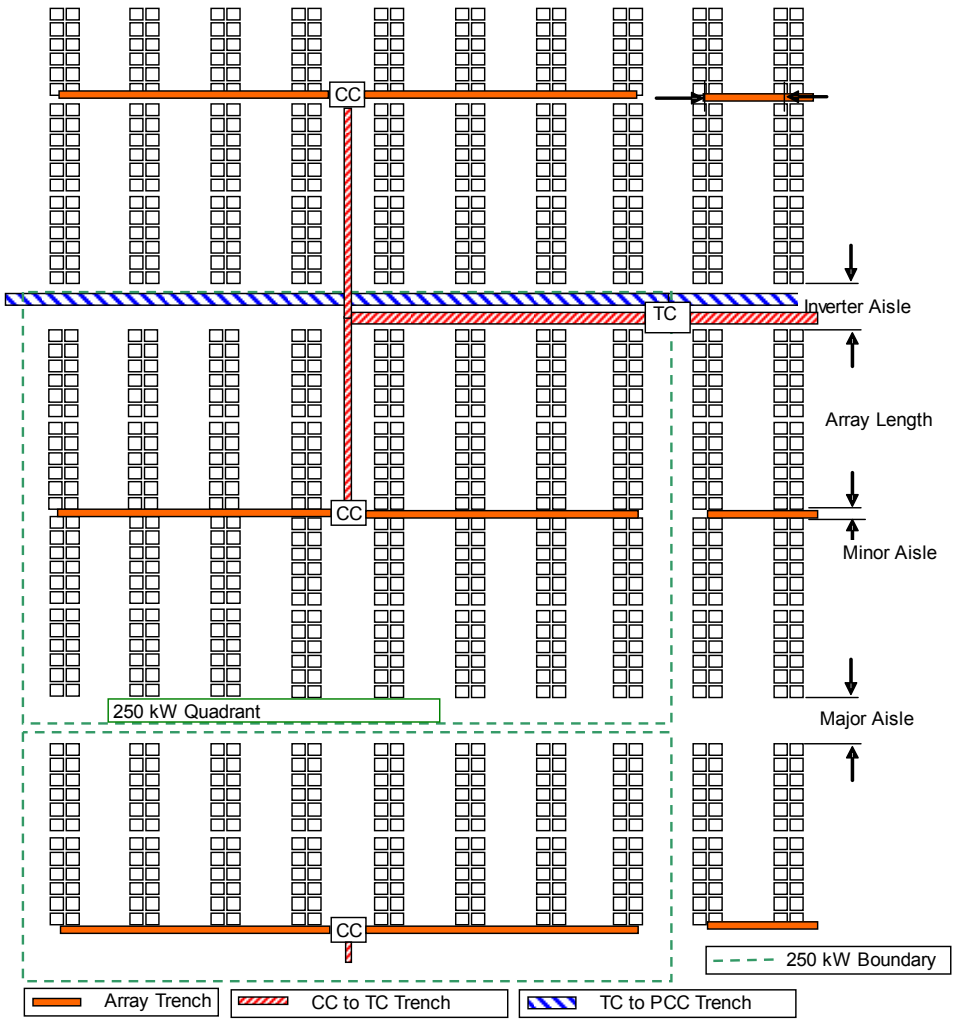
5,968 kW



Emcore CPV Field Connections

CPV Array Field Design

- Arrays oriented in a true North – South alignment.
- Sixteen arrays are connected in a 250 kW Quadrant. A Combiner Cabinet (CC) parallels the outputs of the arrays.
- Four 250 kW Quadrants are connected to one Transformation Center (TC) – a 1 MW block.
- Multiple Transformation Centers are connected to a ring bus for power collection and connection to the Point of Common Connection (PCC).
- System optimized for minimal land preparation and minimal conduit trenching.



This is the Beginning
For Renewable Energy in the US
Brown to Green Conversions
And
the Project's Mentioned

Hope to be invited Back with the
"How to Successfully Implement Renewable Energy on Marginal land"
And
Lessons Learned"
Thanks!

Brian Gibson
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