Tracking Systems for CPV: Challenges and Opportunities

Tyler Palmer
President, GreenMountain Engineering

Solar Power 2007
September 27th, 2007

GreenMountain Engineering

GreenMountain Engineering

- Design engineering consulting firm
  - Clean Technology Innovation
  - Product design and manufacturing development
  - Design, analysis, technology assessment
- GreenTools products
- Experience in solar and CPV

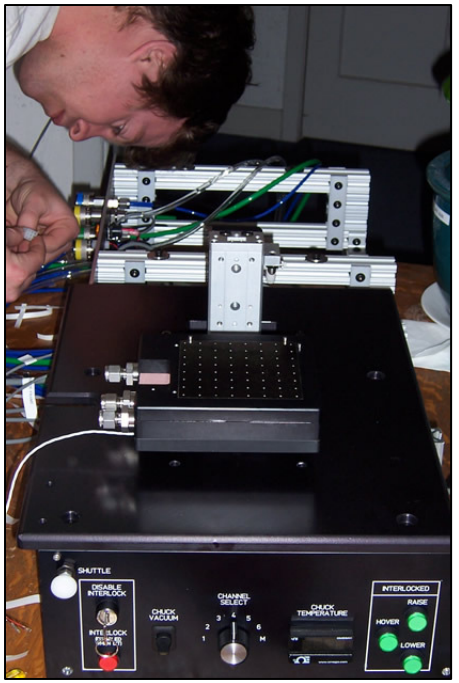


Image: GreenMountain Engineering

evergreensolar Think Beyond.

SUNPOWER

ADVENT SOLAR

SolFocus

SOLIANT ENERGY

The Promise of CPV

Image: Solon AG

Image: SolFocus

- **Lower energy costs ($/kWh)**
- Utilize high-efficiency/multi-junction cells
  - ~40% now; theoretically > 50%
  - Better aperture efficiency (W_p/m^2 of module)
  - Greater energy density (kWh_a/m^2 of land)?
- Improved capacity factor (kWh_a/W_p)
  - primarily due to tracking
- Reduce dependence on solar-grade silicon

The Challenges of CPV

- Direct Normal Irradiance
- Optical design
- Thermal management
- System integration
- Cost control
- Reliability
- ***TRACKING***
  - Pointing accuracy
  - Stiffness and alignment of array
  - Reliability, reliability, reliability!
  - Maintenance

Thermal stress of solar cell under concentration

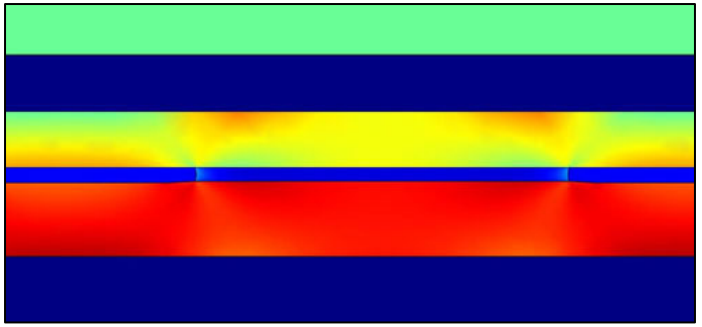


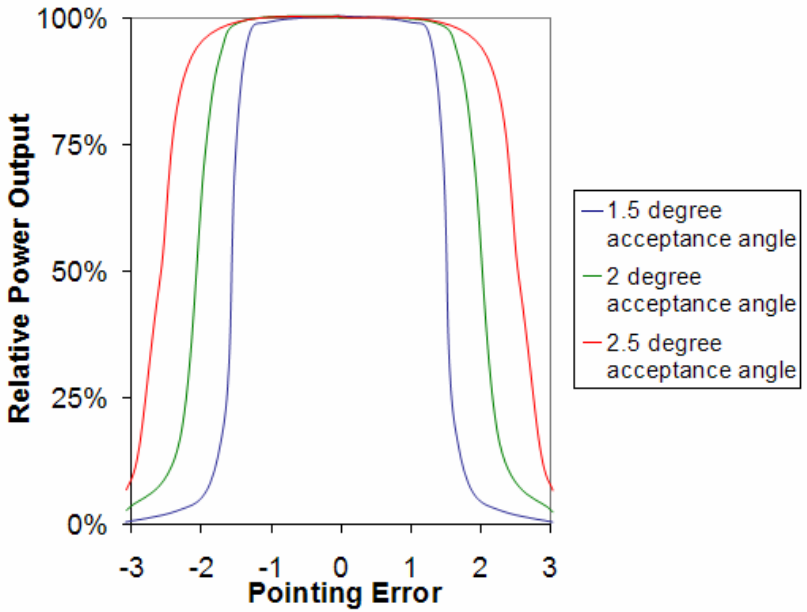
Image: GreenMountain Engineering

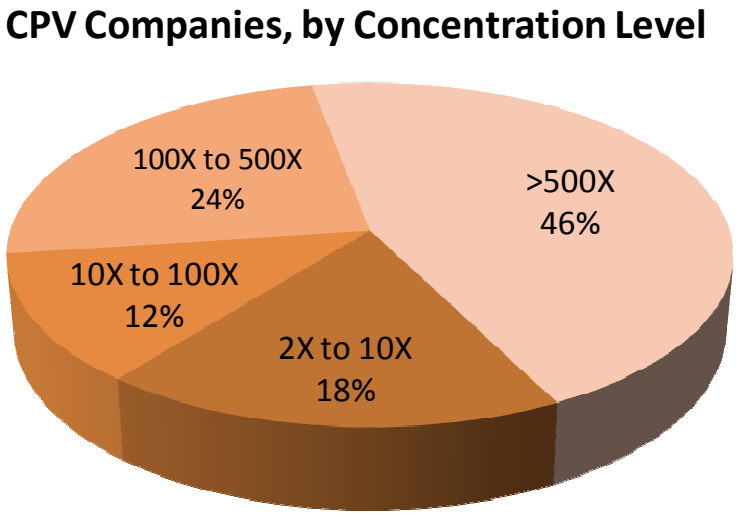
Tracker, following European windstorm Kyrill Jan. '07.

Image: Photon International

Tracking is Essential to HCPV

- Flat panel: 5 degrees is sufficient (cosine error)
- HCPV requires higher pointing accuracy
  - Poor tracking means almost no power
- Accuracy requirements increase with concentration





Source: Photon Magazine (April '07)

GreenMountain Engineering

Tracker Systems

SunPower

Image: SunPower

Flat Plate

Solon

Image: Solon AG

Solar ONE and Two

Image: NREL

Heliostat

Stirling Energy Systems

Image: Stirling Energy Systems

GreenMountain Engineering

Tracker Systems

Concentrating Photovoltaics

SolFocus

Image: SolFocus

Amonix

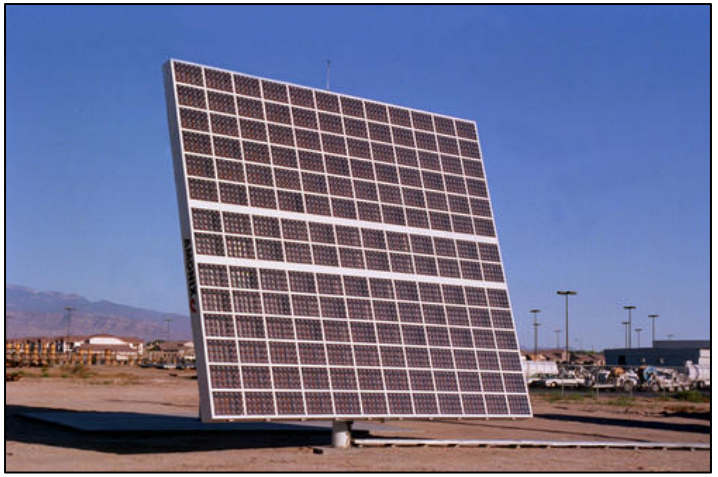


Image: NREL Photographic Information Exchange

Entech

Image: Entech

Soliant Energy

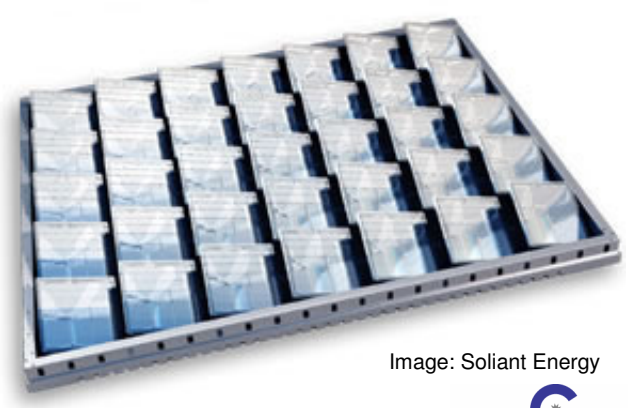
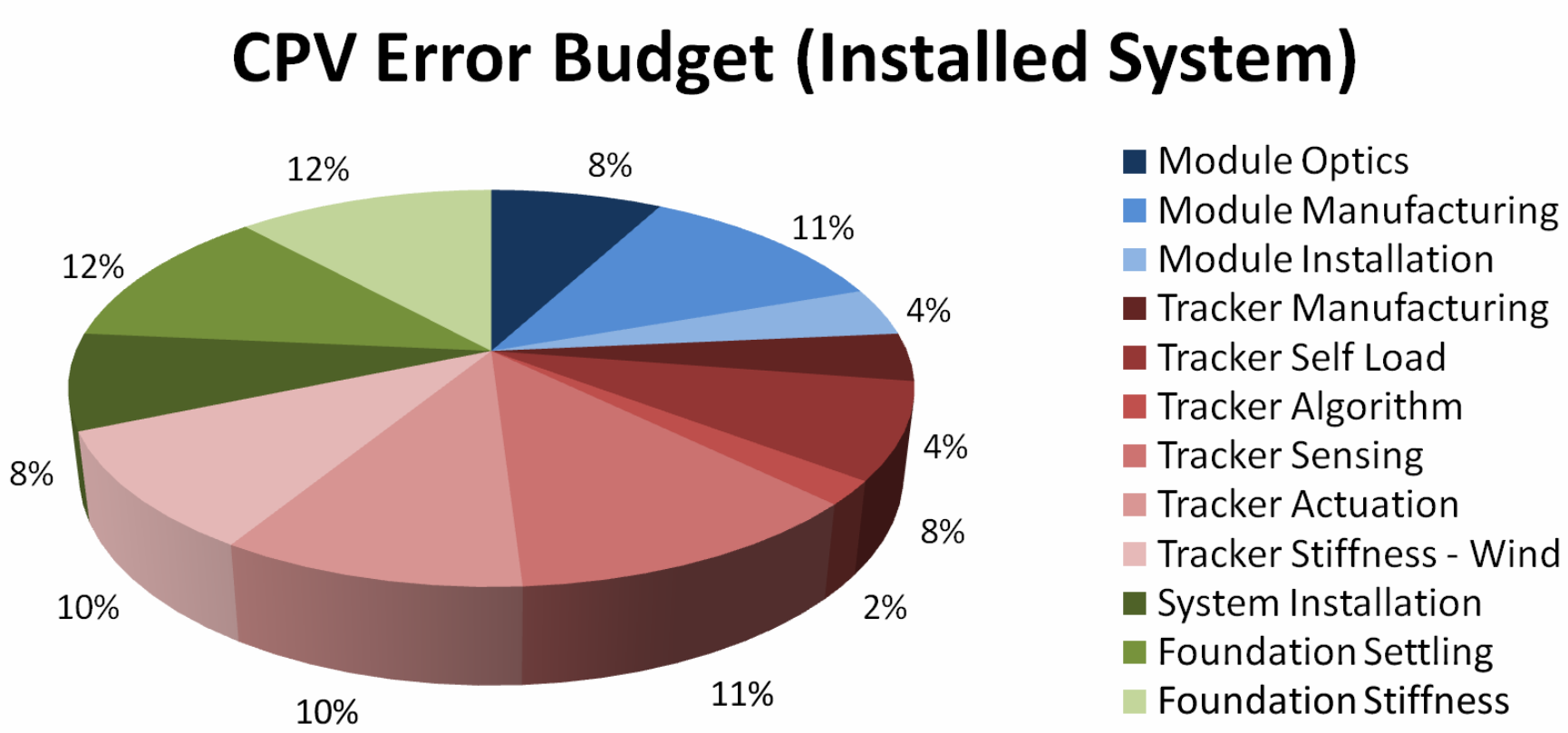


Image: Soliant Energy

GreenMountain Engineering

Error Budget

- Important to design as an integrated system
- No single error dominates



GreenMountain Engineering

Mechanical Design

- Structure:
  - Stiffness-limited not strength limited
  - Stiffness/cost suggests steel and concrete
- Actuators
  - Backlash, cost, reliability
  - Position feedback
- Size
  - Cost and stiffness tradeoffs
- Substantial room for innovation

Image: GreenMountain Engineering

Controller Design

- Open Loop: Calculates expected solar position
  - Pro: simple, robust, theoretically very accurate
  - Con: clock errors, install calibration, settling, linearity
- Closed loop: Uses sun sensor or power feedback
  - Pro: looser tolerances, accurate
  - Con: complex control, low light, shading
- Hybrid
  - Pro: high accuracy and robustness
  - Con: increased complexity
- Ruthless cost control is critical
- Substantial room for innovation

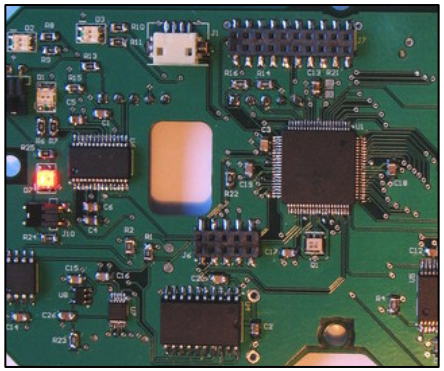


Image: GreenMountain Engineering

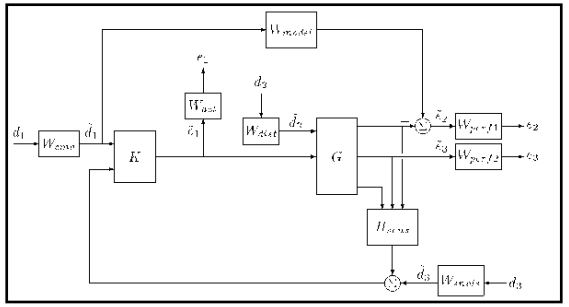


Image: Mathworks

GreenMountain Engineering

Manufacturing

- Now
  - Labor intensive, low-volume
- Future
  - Efficient high-volume manufacturing, resembling automotive industry
    - Stamped, cast, and extruded components
  - Integrated with module manufacturing?
  - Minimal machining & hand welding
- Substantial room for innovation

Image: thefabricator.com

Image: NREL

Tracker Testing

- ISFOC recommends multi-year testing
- In-field testing
  - Positioning accuracy
  - System degradation
  - Real-world module performance
  - Maintenance requirements
- Accelerated life testing
- IEC Standards
  - IEC 62108: CPV qualification standard
  - IEC standard for Flat PV and CPV trackers

Sun Location Sensor: characterizes tracker error

Image: GreenMountain Engineering

Installation and Maintenance

- Installation
  - Installation costs should be <<$1/W
  - Include all components of installation cost
    - Foundation, wiring, crane, earthmover, manpower, etc
  - Flat pack shipping and design for installation
- Maintenance
  - Must be *very* small/unit/year
  - Lubrication?
  - Recalibrate as necessary
  - Detect and replace failed modules
  - Replace failed tracker components

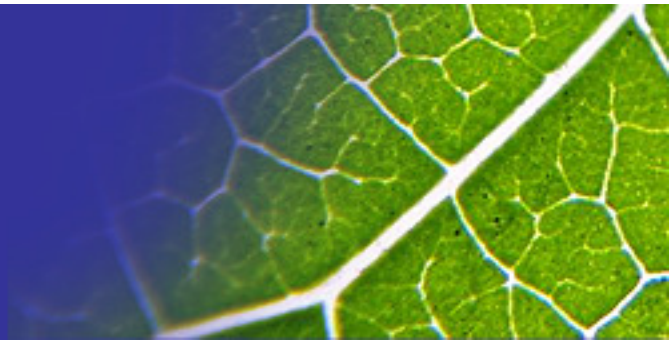
Image: Conentrix Solar

Conclusions

Image: GreenMountain Engineering

- Tracking is critical to CPV's success
- Multiple feasible approaches to concentrators & trackers
- Industry is young and growing quickly
- Take lessons from other industries
- Challenges remain
- Still interesting problems to solve and fame to earn

Thank You



GreenMountain Engineering