

CSP Program Trough Technology Overview

**CSP Peer Review
November 7, 2001**

**Hank Price, Rod Mahoney, Jim Pacheco – SunLab
Dave Kearney – K&A**

Trough Technology Team

Industry

Augustyn & Company, Barber Nichols, Bibb & Associates, Cytec, Duke Solar, Exergy, FSI, FPL Energy, Industrial Solar Technology, Kearney & Associates, KJC Operating Company, Ozark Fluorine, MCAD, MWE & Associates, Nexant/Bechtel, Ormat, PNNL, Reflective Energies, Sargent & Lundy, Solel, Solutia/Monsanto, Spencer Management, Sunray Energy Inc., Union Carbide

Universities

SUNY Albany, University of Alabama, UNLV, UW Madison

SunLab

Dan Blake, Kye Chrisman, Jim Grossman, Mary Jane Hale, Vahab Hassani, Darrell Johnson, David Johnson, JJ Kelton, Cheryl Kennedy, Bill Kolb, Rod Mahoney, Luc Moens, Jim Pacheco, Hank Price, Earl Rush, Steve Showalter, Steve St. Laurent, Tim Wendelin

History of Large-Scale Commercial CSP Development – the 10 SEGS Plants

- Development Years: 1984-1990
 - PURPA, Tax Incentives, and Special PPAs allowed development
 - Luz Built 9 Parabolic Trough Plants: 14-80 MWe, 354 MWe Total
 - Declining Energy Prices and Incentives
 - Annual Renewal of Incentives required \Rightarrow Increased Cost
 - Delay of 1990 Solar Property Tax Extension \Rightarrow Luz Bankruptcy
- Last Decade ...
 - Economic Downswing \Rightarrow Excess Power Capacity
 - Restructuring of Utility Power Sector
 - Trough Development Efforts Focus on International Markets
 - No New Plants in Last 10 Years
- Today
 - All plants still operating after 11-16 years
 - At 150MW Kramer Junction site, performance is excellent, with many performance records set over last few years
 - O&M costs significantly reduced as performance has increased

Examples of Cost Reduction Potential

Large scale systems

1997 Study - Current Trough Technology Cost

Action	% Cost Reduction	¢/kWh Reduction Based on 14 ¢/kWh base
Increase size from 50 to 160 MW (trough/tower)	20%	-2.8
Mass production	15-30%	up to -4.0
Technology development	10%	-1.4
Multiple siting	25%	-3.5
GenCo financing	10%	-1.4
Tax equity	18%	-2.5
2% debt financing	30%	-4.1

**Post Luz
R&D Already
Demonstrated**



Most of these actions can combine for a strong cumulative effect

Parabolic Trough Roadmap

A Pathway for Sustained Commercial Deployment of Solar Thermal Technologies

Trough Roadmap Working Group

Jan 20-22, 1998 - Boulder, Colorado

- Industry
 - KJC Operating Co.
 - (Duke Solar)
 - Bechtel
 - SOLEL
 - Pilkington Solar Int.
 - Industrial Solar Tech.
 - Kearney & Assoc.
 - Luz Experts
- Labs
 - DLR/MD-PSA
 - SunLab - NREL & Sandia
- Other
 - The World Bank
 - California Energy Commission

Trough Roadmap Overview

- Future Vision for Troughs
 - Power Market Scenarios
 - Market Vision
 - Technology Vision
- Trough Roadmap
 - Key Development Areas
 - Technology Cost and Performance Goals
 - Technology Development Plan

Roadmap Vision

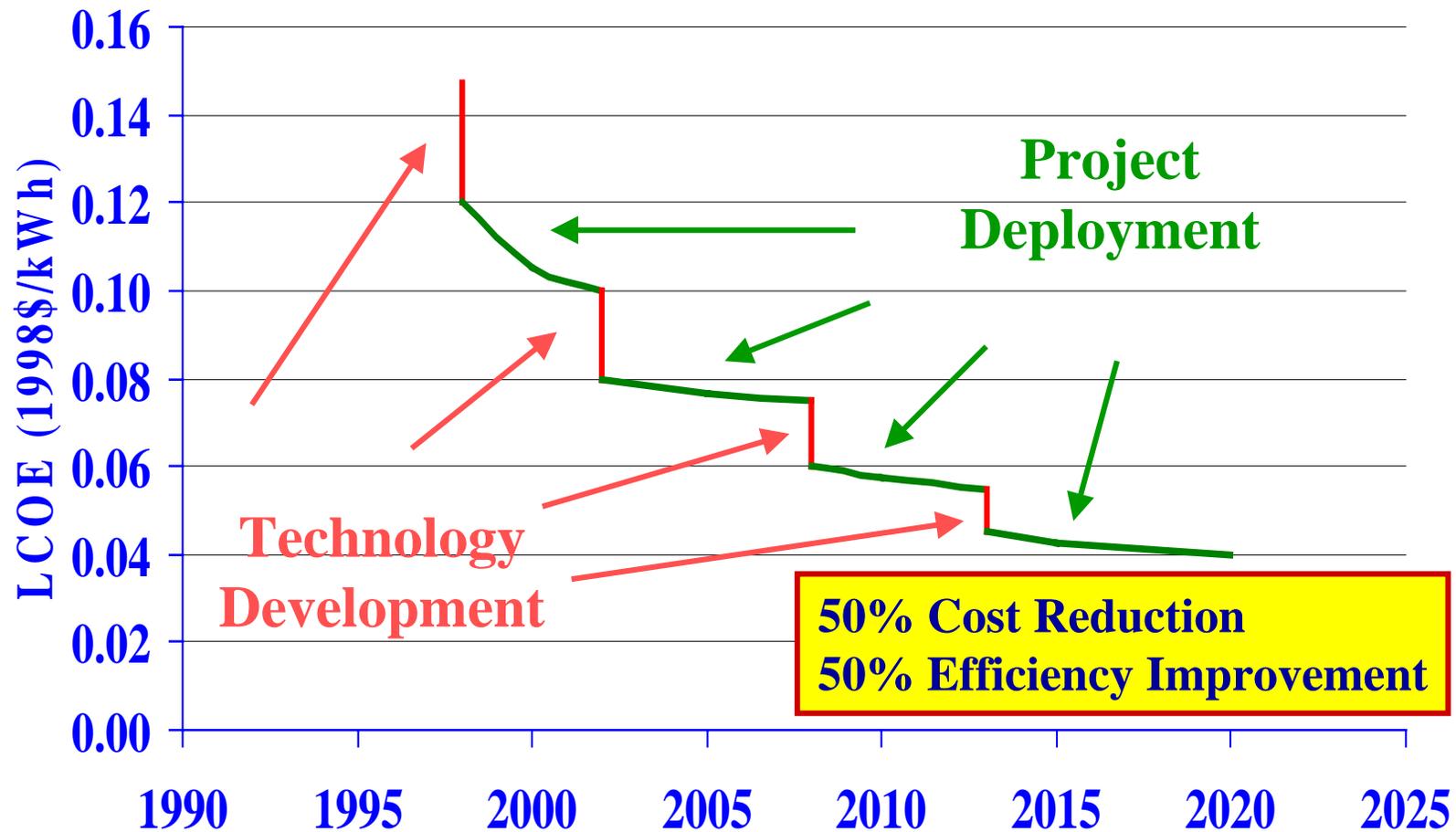
Market Vision

- Markets:
 - NT: High value/cost markets and opportunities
 - LT: Competitive with conventional generation
- Competition:
 - NT: Green Power (Wind)
 - LT: Fossil (Intermediate Load)
- Market Development
 - Single subsidized projects will not reduce future project costs
 - Need project aggregation to reduce costs
 - Focus on IPP (not utility)

Technology Vision

- **Significant cost reductions and performance improvements are possible**
- Deployment and R&D issues
- Near-term and long-term requirements
- Needed stronger consensus & collaboration

Trough Roadmap Vision



Concentrating Solar Power

Sun Lab

Sandia National Laboratories, Albuquerque, NM
National Renewable Energy Laboratory, Golden CO

DOE Parabolic Trough Focus

- Advance the state-of-the-art of trough technology for near-term applications
- Encourage technology advances that will support required future cost reductions
- Encourages the development of a U.S. trough industry
- Build SunLab capabilities to support trough technology RD&D

CSP Trough Program Focus

- Technology Development
 - Receiver
 - Concentrator
 - Thermal Storage
 - Power Cycle
- Industry Development and Support
 - USA Trough
 - Analysis & Testing
 - Industry Support



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CSP Trough Program Focus

- Technology Development
 - Receiver – Rod Mahoney (SunLab)
 - Concentrator – Rod Mahoney (SunLab)
 - Thermal Storage – Jim Pacheco (SunLab)
 - Power Cycle Integration – David Kearney (K&A)
 - Industry Development and Support
 - USA Trough
 - Analysis & Testing
 - Industry Support
- } Hank

USA Trough Initiative

FY99 Solicitation - Phase I

Near-term technology focus

- **Reflective Energies**
 - 10 MWe Trough Organic Rankine Cycle Plant
- **Bechtel/Pilkington**
 - High Impact ISCCS Design
 - Thermal Storage for ISCCS and Rankine Trough Plants
- **Duke Solar**
 - Trough Concentrator Development
- **MWe**
 - HCE Reliability Analysis
- **Industrial Solar Technology**
 - Analysis of SEECOT Concept

FY00 Solicitation - Phase II

Open technology focus

- **Industrial Solar Technology**
 - Concentrator Development
- **SUNY Albany**
 - Satellite DNI Mapping
- **Augustyn & Company**
 - Improved Low-Cost DNI Measurement System
- **Kearney & Associates**
 - Assessment of Molten-salt HTF for trough plants
- **Reflective Energies**
 - ORC Trough Plant Detailed Design
- **Duke Solar**
 - Trough collector Development
 - Small ORC System Assessment



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USA Trough Initiative

Accomplishments

- Two US vendors working trough concentrator designs for high temperature power applications
- Near-term and next generation thermal storage technologies developed for troughs
- Improved DNI resource assessment for projects
- Advanced power cycle integration options

Analysis & Testing

Focus on applying SunLab capabilities to trough technology development needs

- **Analysis**

- Trough process, performance, economics modeling
- Optical tools (SolTRACE)
- Thermal storage (1D Thermocline Analysis, CFD, TRNSYS)
- Receiver thermal performance

- **Testing**

- Specialized tools (LFOCS)
- NSTTF Rotating Test Platform
- SEGS Testing Agreements

Industry Support

Focus on activities to support current and future trough projects

- SEGS Support
- SEGS Testing Partnerships
- Trough Technology Outreach
- SEGS Technology Upgrade

SEGS Testing Partnerships

- **Creates new approach to work with SEGS Plants**
 - Multi-year test and support contracts with each O&M company
 - A framework to cover out-of-pocket expenses for testing
 - Fast turnaround to implement tasks
- **Benefits**
 - Allows testing in commercial plant environment
 - Reduces cost for testing
 - Taps special expertise and resources of O&M companies
 - Provides access to plant specific data
- **Testing to be conducted under agreements**
 - **Solel UVAC Receiver Test** **In Progress**
 - **Flabeg High Wind Mirror** **In Development**
 - Concentrator testing (LS-2, LS-3, Duke, IST, EuroTrough)
 - Power cycle and solar field efficiency testing
- **Status**
 - Testing agreements in place with: Sunray, KJCOC, & FPL Energy

Trough Technology Outreach

Improved Communication with Industry & Stakeholders

- Trough Industry Steering Committee
- Trough Technology Workshops
 - Roadmap 1998
 - Ontario 1999
 - Madison 2000
 - DC 2001
- TroughNet website



CEC Proposal – “SEGS Upgrade”

- Program
 - All SEGS Participating
 - Budget
 - ~\$25M from CEC
 - Leveraged DOE R&D funding
 - Industry Cost Share
- Activities
 - Receiver and mirror replacements
 - New technology demonstration (receiver & mirror)
 - Thermal storage demonstration
 - New collector technology demonstration
- Program Benefits
 - 80 MWe Solar Power Plant Equivalent
 - \$400/kW cost
 - < 2 year payback (to California and Owners)

Trough Technology

Issues & Opportunities

- **Industry Interactions and Support**
 - Work closer with industry
 - Improve lab support to O&M companies
- **Slow progress**
 - It takes time to develop new projects
 - Chicken and egg issue
 - Growing pains
 - need dedicated SunLab staff for trough activities
- **Technology**
 - Availability of trough concentrator for near-term projects
 - Risk of near-term thermal storage

Trough Technology

Successes

- Technology
 - Promising selective coatings and receiver designs
 - Near-term thermal storage option for troughs
 - Promising advanced HTFs under development for storage
 - New power cycles, CC integration, and small system development
- Expanding industry (Duke Solar, Nexant, ORC Industry)
- Collaboration/Teaming (SunLab, Industry, International)
- Innovative testing agreements with SEGS operators
- Communications/Information Transfer