

# Costs of New Renewable & Fossil-Fueled Generation in California Photovoltaic & Concentrating Solar Thermal



*Knowledge to Shape Your Future*

California Energy Commission

**DOCKETED**  
**13-IEP-1B**

TN # 69852

MAR 07 2013

## CEC Workshop

## March 7, 2013

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## **Costs of New Renewable Generation Photovoltaic & Concentrating Solar Thermal**

- ❑ A forecast of installed costs
  - capital cost per unit generating capacity- \$ / MWe
  - low, mid, and high cost outlooks through 2030
  - based on academic & industry studies & forecasts
  - currently operating and planned costs included
  - recognizing worldwide growth in installed plant capacity & technological advances
- ❑ California costs, siting, & solar performance

# Primary Cost Studies and Forecasts

- ☐ 2012 DOE Sunshot Vision Study
- ☐ 2012 NREL/Black & Veatch Cost and Performance Data For Power Generation Technologies
- ☐ 2010 EIA Updated Plant Costs
- ☐ 2012 Photon Magazine PV module spot pricing
- ☐ 2010 LBNL Tracking the Sun
- ☐ 2010 NREL/Sandia Current and Future Costs for Parabolic Trough & Power Tower Systems in US Market
- ☐ Large Plant Data (CEC siting info, IOU advice letters for PPA, trade publications, news, installer websites)

## Range of Commercial Embodiments

### ☐ Photovoltaic

- from 2 to 500+ MWe capacity
- modules *fixed* or modules *tracking*  
(tracking increases cost & capacity factor but not capacity)

### ☐ Concentrating Solar Thermal

- 50 – 230 MWe capacity steam turbine
- receiving *troughs* or receiving *towers*
- thermal energy *storage* option  
(storage increases cost & capacity factor but not capacity)

## Assumed Commercial Embodiments – Photovoltaic

- ❑ two 100 MWe plants:
  - modules fixed
  - modules tracking
- ❑ most operational projects range 2-60 MWe
- ❑ ~6000 plants worldwide
- ❑ planned plants up to 10x larger
- ❑ 10% of planned MW from 500+ MWe plants

## Assumed Commercial Embodiments – Concentrating Solar Thermal

- ❑ three plants:
  - 150 MWe trough without storage
  - 200 MWe trough with 6 hrs storage
  - 230 MWe tower with 11 hrs storage
- ❑ ~50 trough and ~6 tower plants worldwide
- ❑ thermal energy storage raises installed cost but lowers levelized cost of energy
- ❑ no natural gas backup boiler

## Assumed Plant Annual Performance– Annual Capacity Factor

### ☐ Photovoltaic

- fixed array: 21.0 - 25.3 %
- tracking array: 27.3 – 31.5 %

### ☐ Concentrating solar thermal

- trough without storage: 20 – 29 %
- trough with 6 hrs storage: 41 – 43 %
- tower with 11 hrs storage: 45 – 62 %

### ☐ Estimated with NREL's System Advisor Model

# Cost Forecast Key Assumptions

## Photovoltaic

- ❑ learning curve trajectory forecasts apply to
  - module costs
  - inverter costs
- ❑ Sunshot balance of system cost forecasts are optimistic but reasonable targets
  - If ambitious reductions achieved by 2020, further cost reductions will be incremental

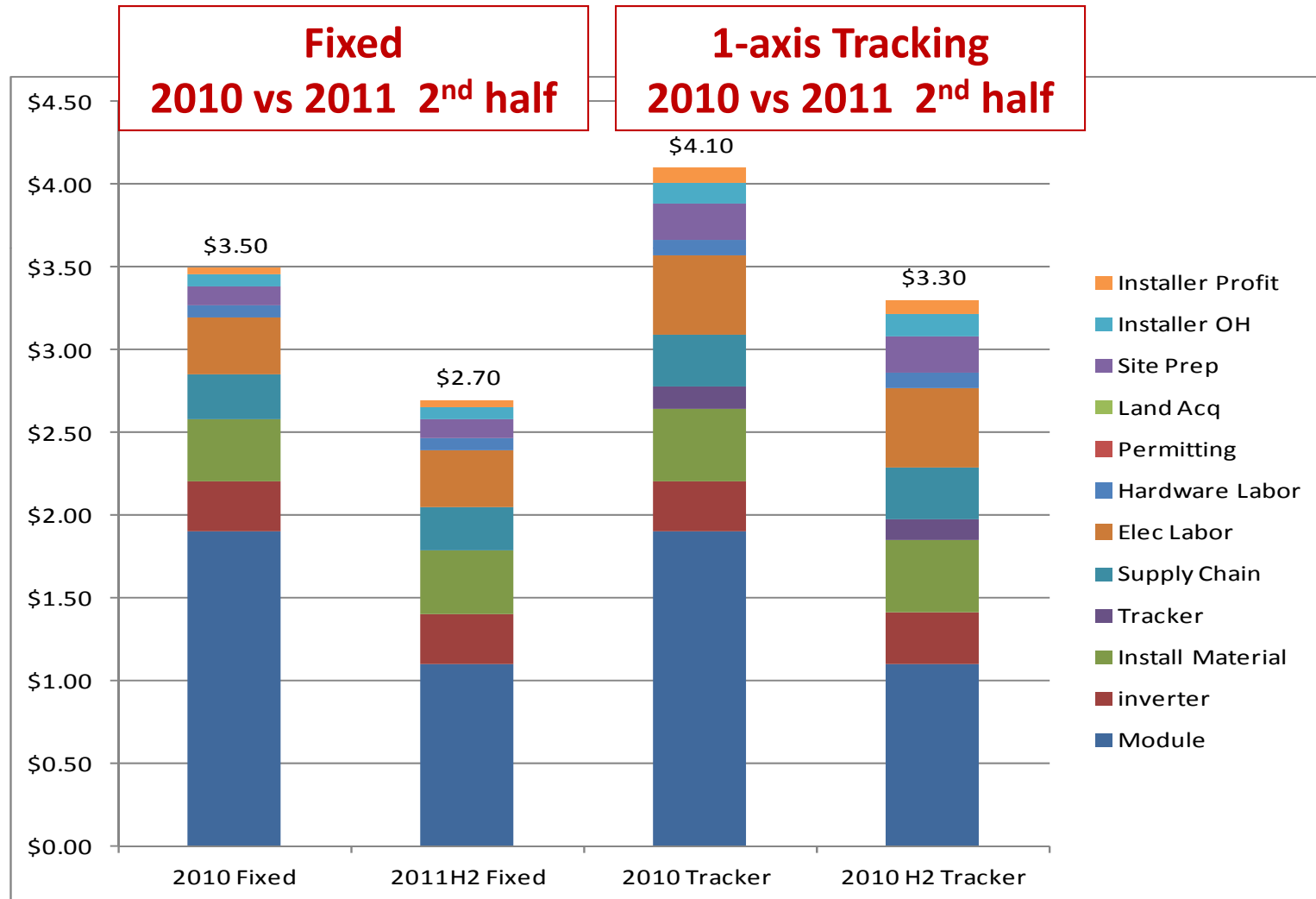


# Photovoltaic Plant

## Installed Cost Components

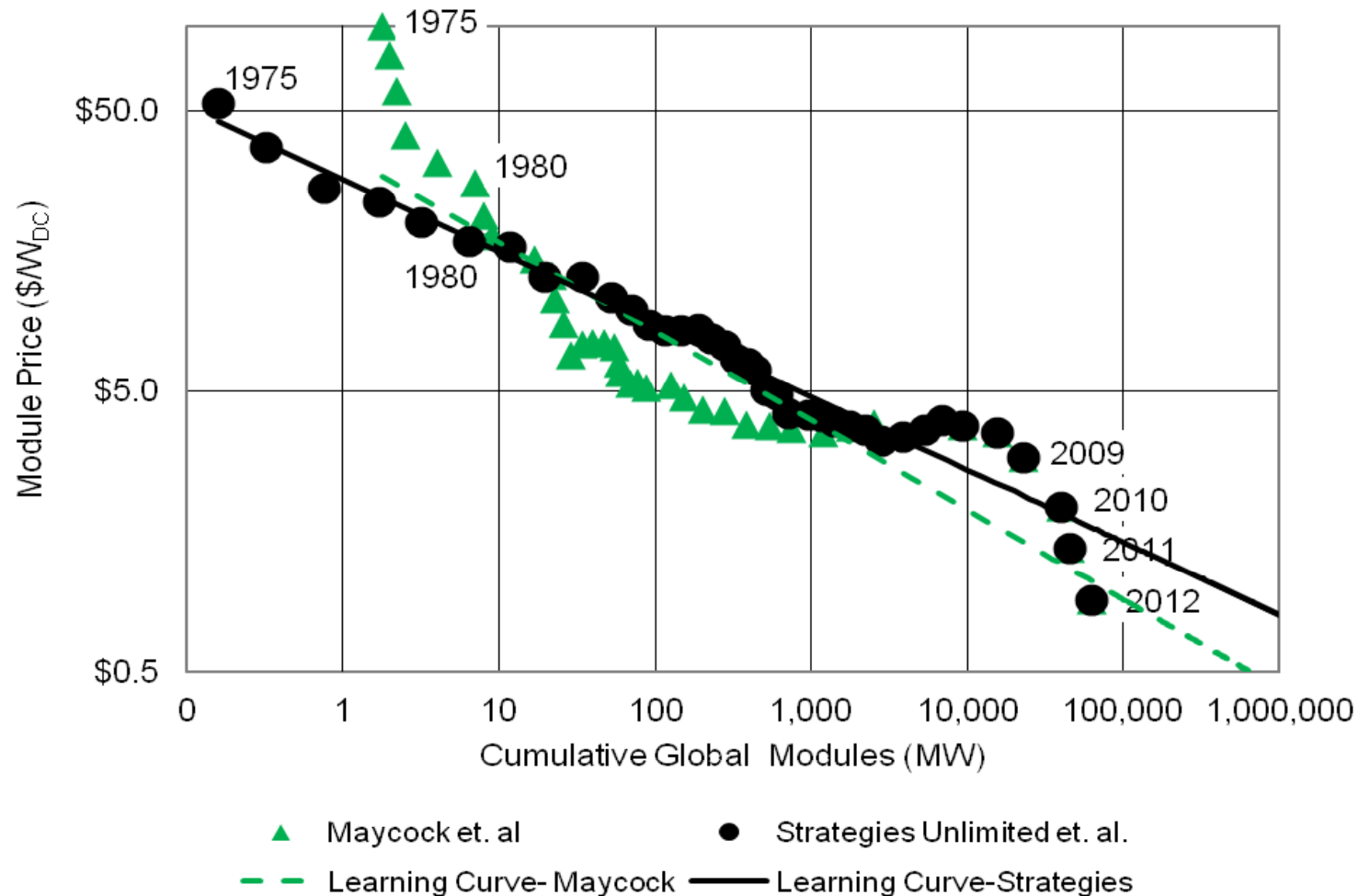
- ☐ Modules
- ☐ Power conditioning – inverter
- ☐ Balance of system:
  - Non-inverter hardware
  - Non-hardware
- ☐ Soft costs

# PV Module & Project Cost Drop 2010-2011



# PV Module Price Trend

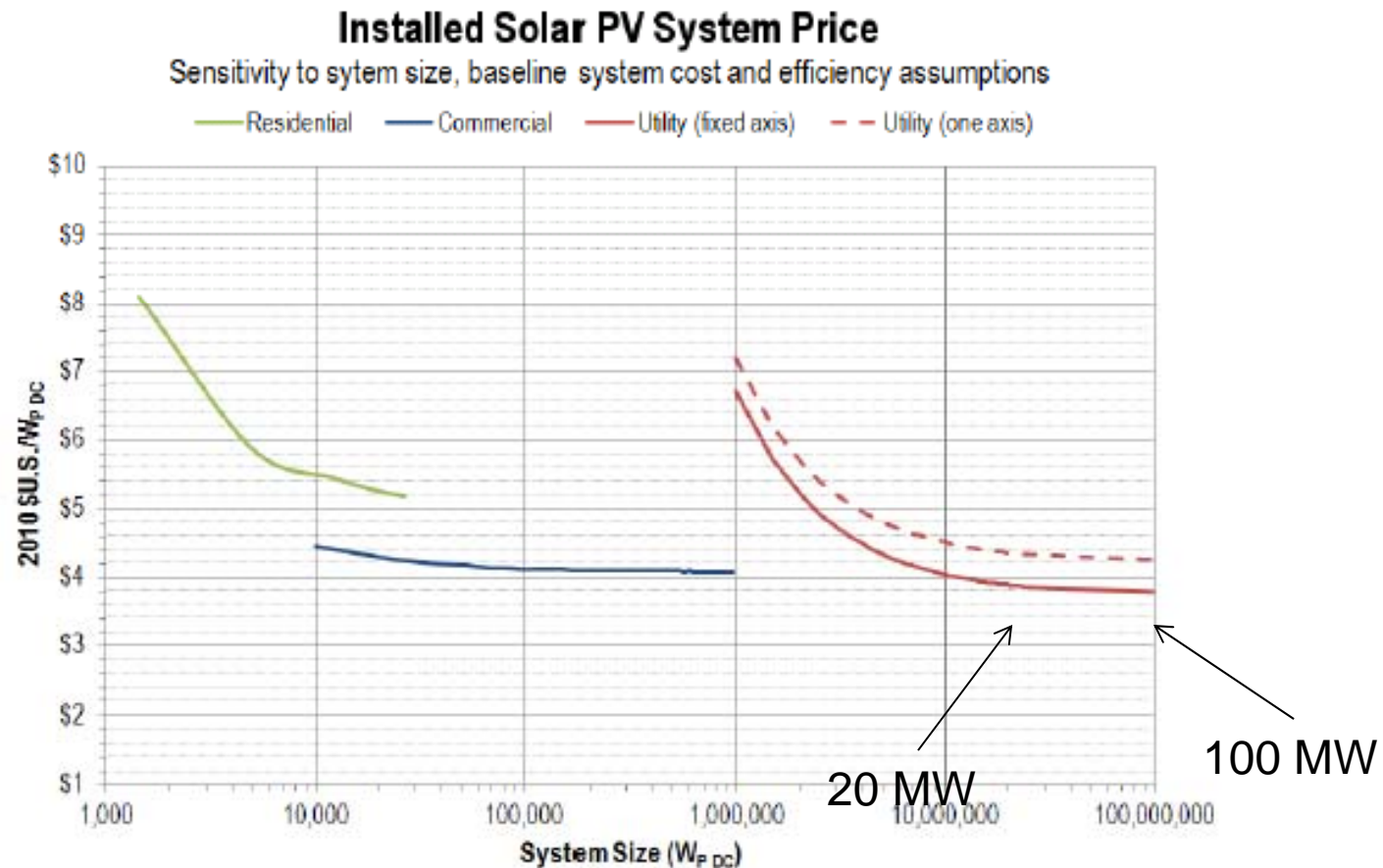
## Learning Curves and Cumulative Capacity



## PV Module Price Trend

- ❑ Now below historical learning curve
- ❑ Beating curve could continue
  - most believe this will be the case
- ❑ Market could correct
- ❑ Cumulative volume drives learning
  - Low Growth assumed 10% per year
  - Moderate Growth assumed 20% per year after 2016
  - High Growth assumed 25% per year after 2016

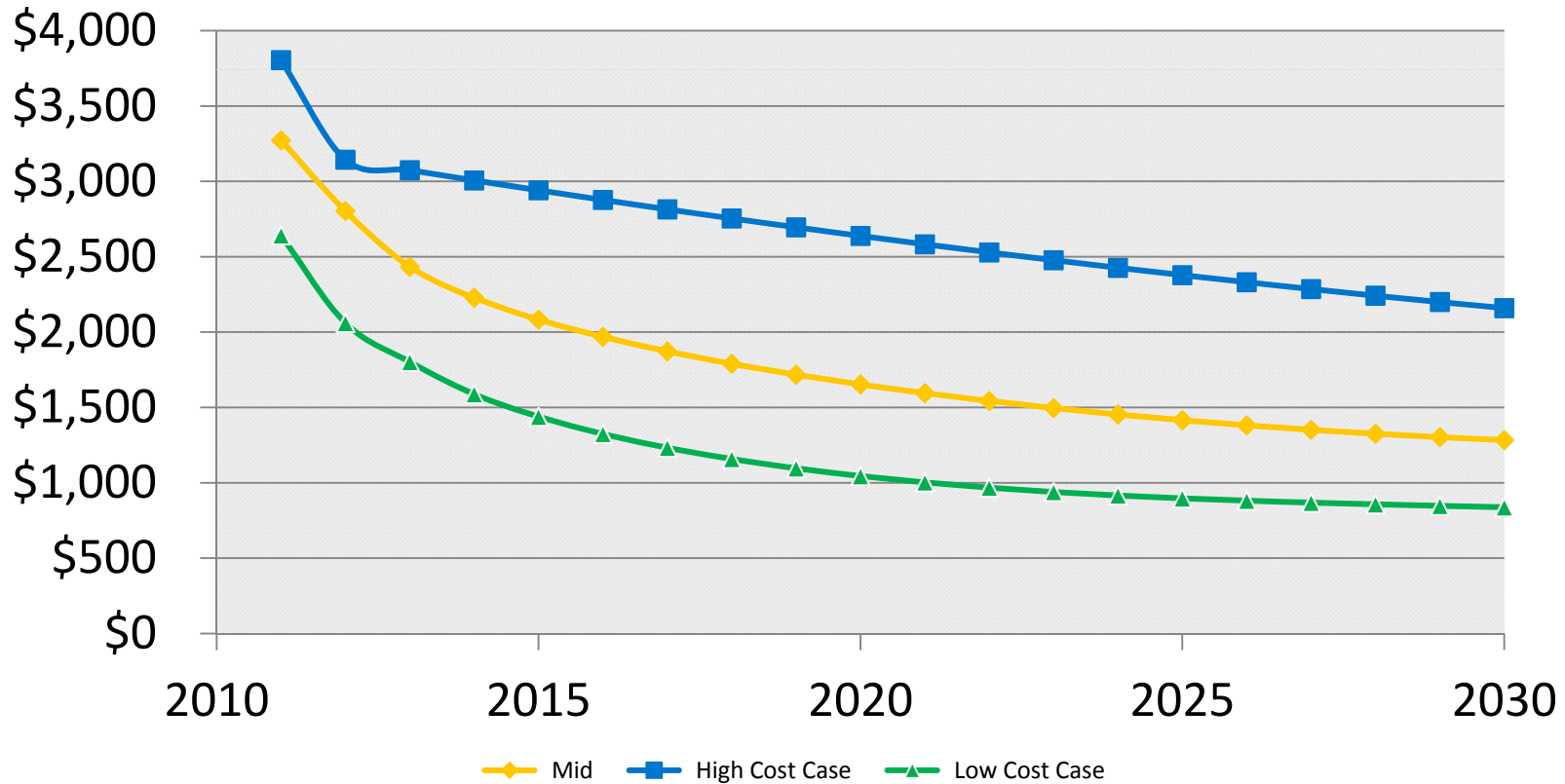
# PV Plant Capacity and Unit Costs



- ❑ NREL/TP-6A20-53347 , February 2012. Figure 4. Economy-of-scale benefits
- ❑ 20 MW plant \$/W ~ 100 MW plant \$/W

# PV System Installed Cost Forecast Fixed Array

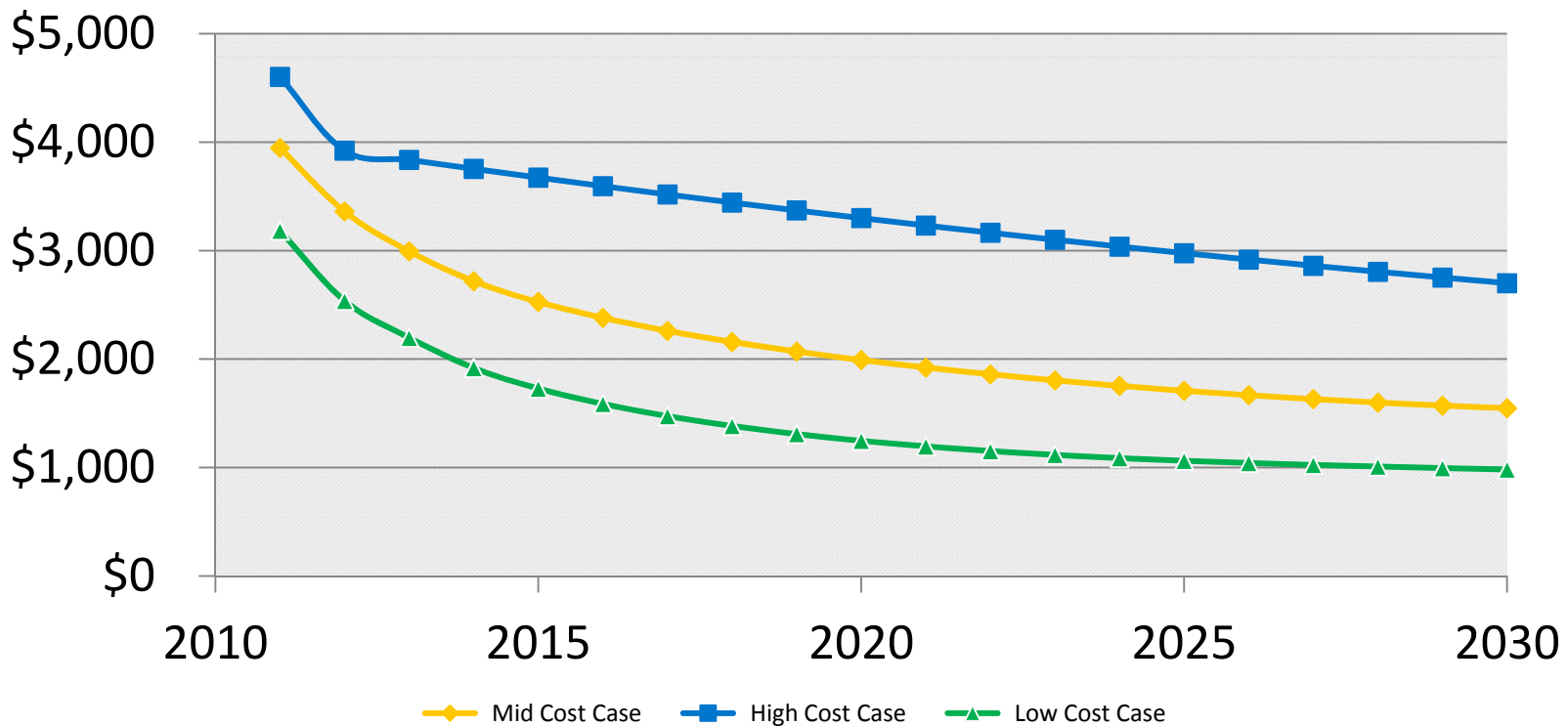
Installed Cost (Real 2011 \$/Gross kW<sub>DC</sub>) Fixed



# PV System Installed Cost Forecast

## 1-axis Tracking Array

Installed Cost (Real 2011 \$/Gross kW<sub>DC</sub>) Tracking





# **Cost Forecast Key Assumptions**

## **Concentrating Solar Thermal**

- ☐ Thermal energy storage adopted to improve economic performance
- ☐ Solar field sizes increased to charge thermal energy storage
- ☐ Dry cooling adopted in later years
- ☐ Individual steam turbine
- ☐ No natural gas backup

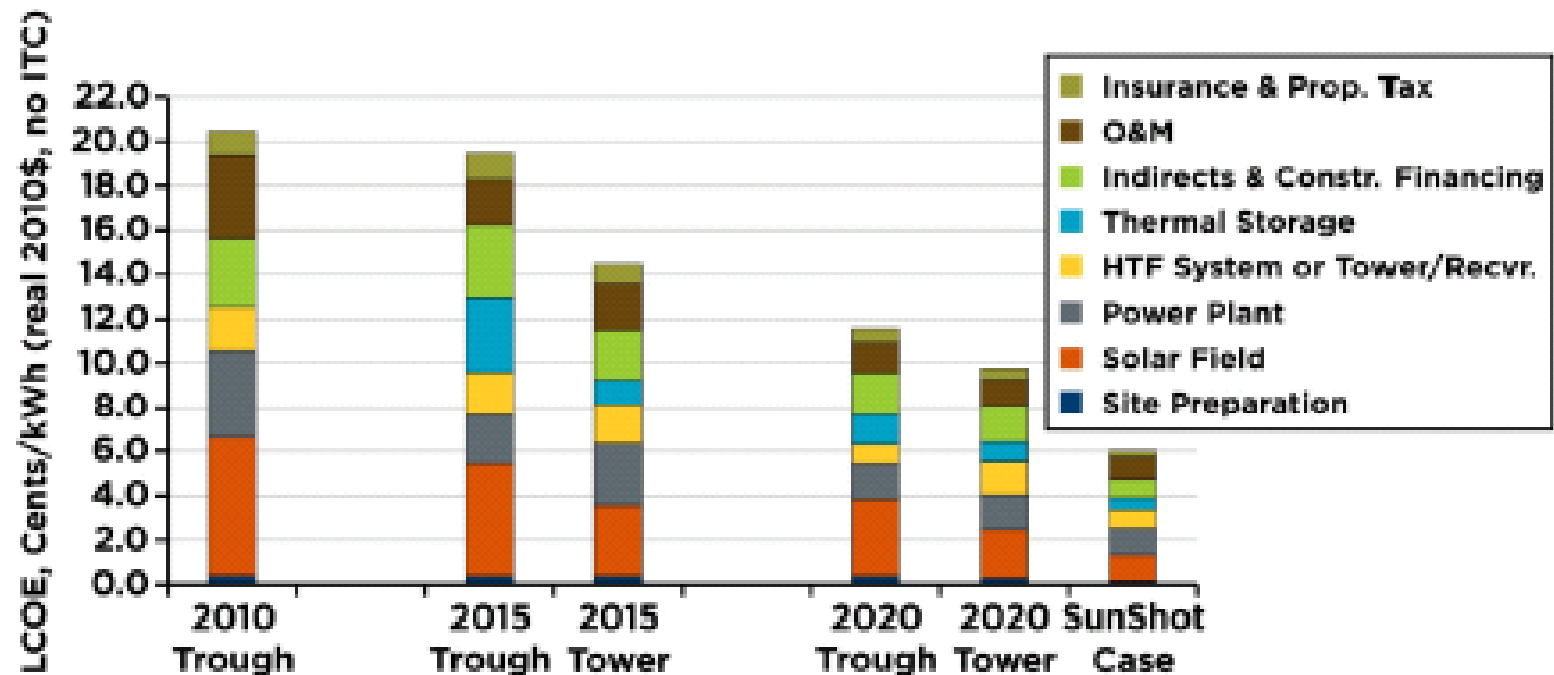


# Concentrating Solar Thermal

## Installed Cost Components

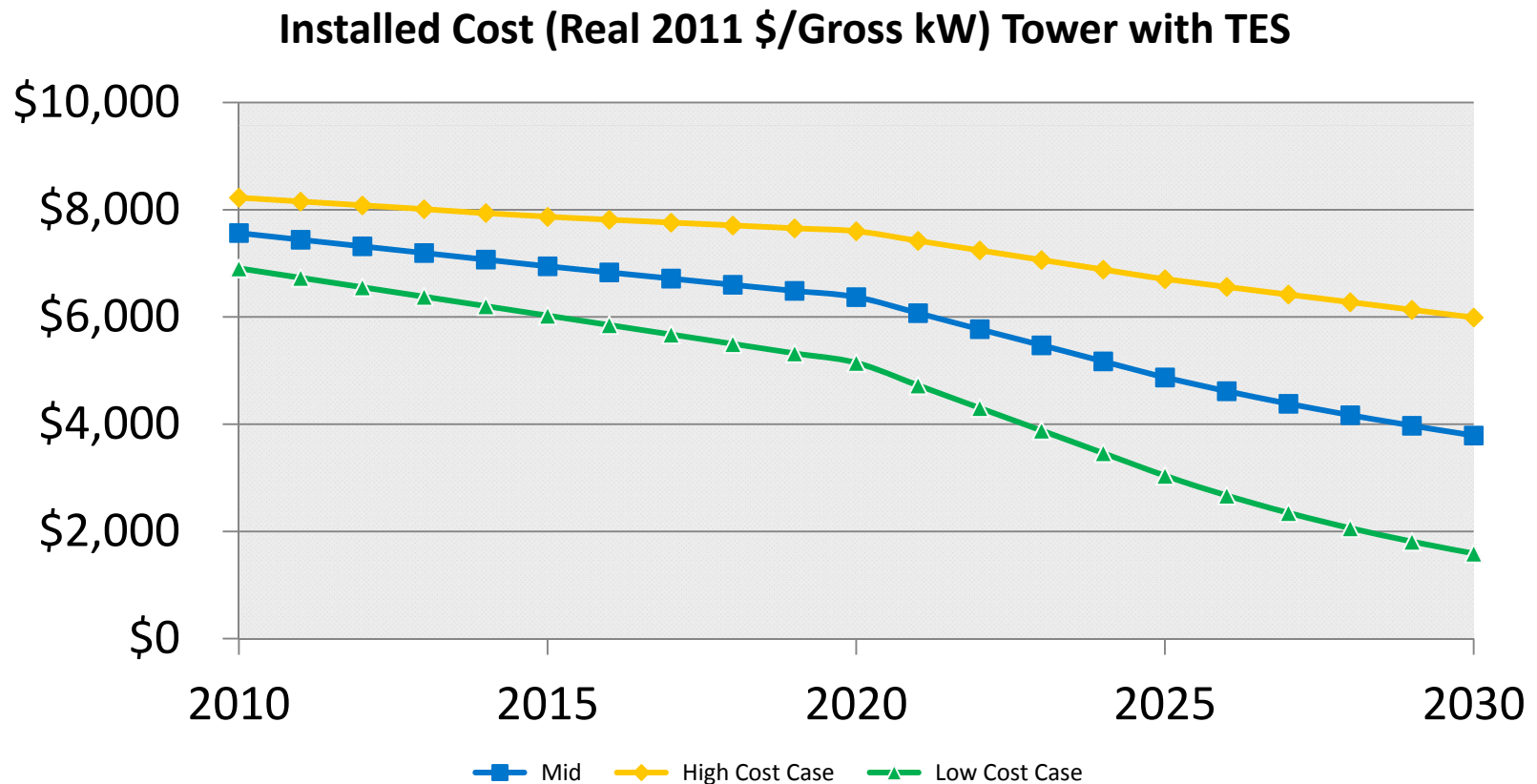
- ☐ Solar field: parabolic troughs, heliostats
- ☐ Heat transfer fluid
- ☐ Power block
- ☐ Thermal storage
- ☐ Balance of system
- ☐ Soft costs

## Concentrating Solar Thermal Components in Levelized Cost of Energy Forecasts



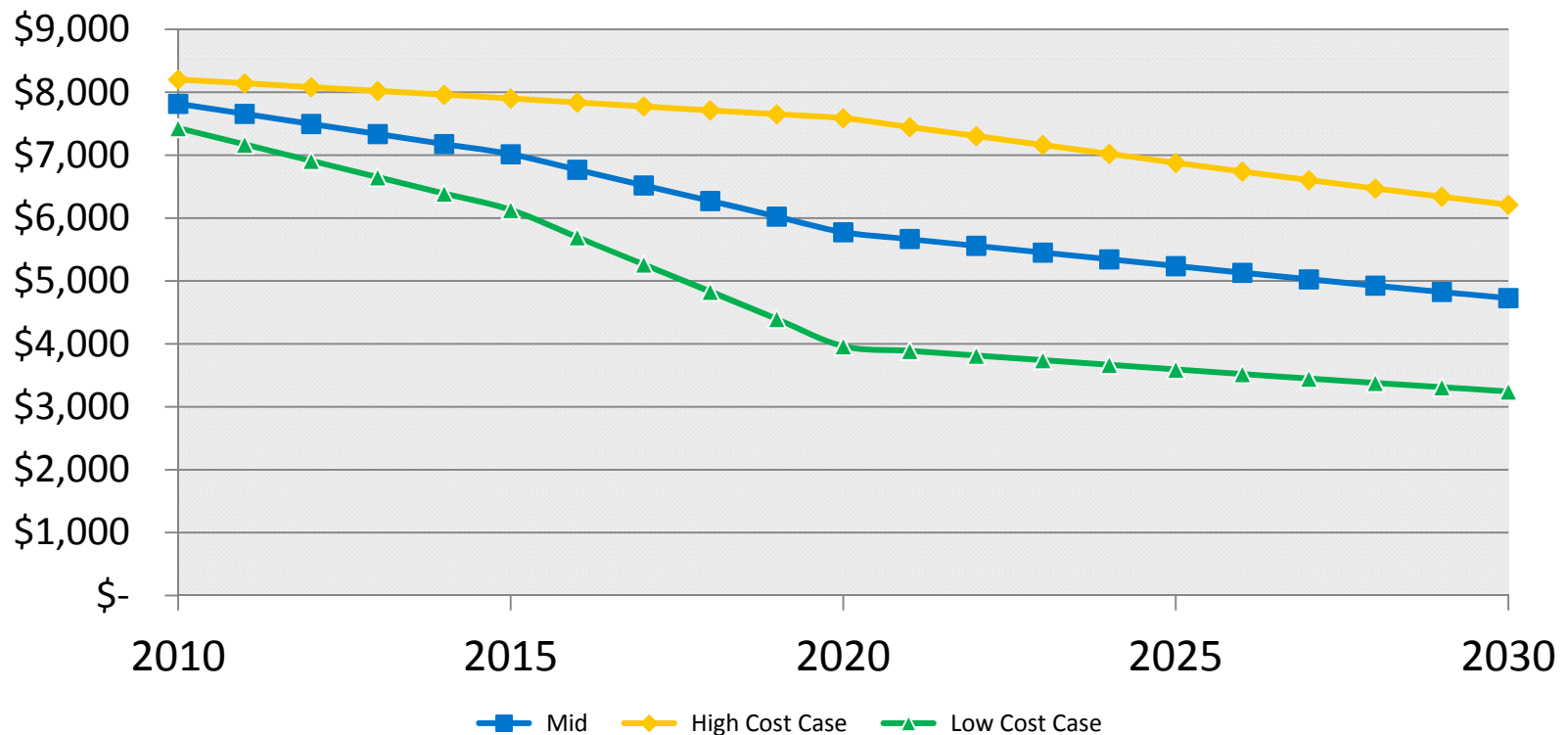
- ☐ thermal energy storage begins 2015
- ☐ solar field is largest component, has largest reductions
- ☐ From DOE SunShot study

# CSP Installed Cost Forecast Tower with Thermal Energy Storage



# CSP Installed Cost Forecast Trough with Storage

Installed Cost (Real 2011 \$/Gross kW) Trough with TES



# CSP Installed Cost Forecast Trough without Storage

Installed Cost (Real 2011 \$/Gross kW) Trough without TES

