



# **OVERVIEW OF THE ENERGY COMMISSION'S COST OF GENERATION MODEL**

Cost of Generation Modeling Workshop

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Joel Klein (916) 654-4822



# TODAY

- Overview of Energy Commission's Cost of Generation (COG) Process
- General Modeling Objectives
  - Model Design Objectives
  - Outputs
  - Data
  - Documentation



# OVERVIEW OF THE COST OF GENERATION PROCESS

- Provide a Biennially Updated Cost of Generation (COG) Model and Produce IEPR COG Report
- Provide a single consistent set of levelized cost and supporting data to support energy studies at the CEC
- Provide Levelized Costs, supporting data, and COG Model to various parties:
  - State entities: governor's office, legislature, CPUC, BOE, CAISO
  - Out of state entities, consultants, students



# GENERAL OBJECTIVES

## COG MODEL

- Produce a transparent, easy to use, flexible model that meets design objectives
- Accurate, internally consistent data
- Quality comprehensive documentation
  - Document data sources
  - Explain how to use the Model
  - Explain model algorithms
  - Define terminology

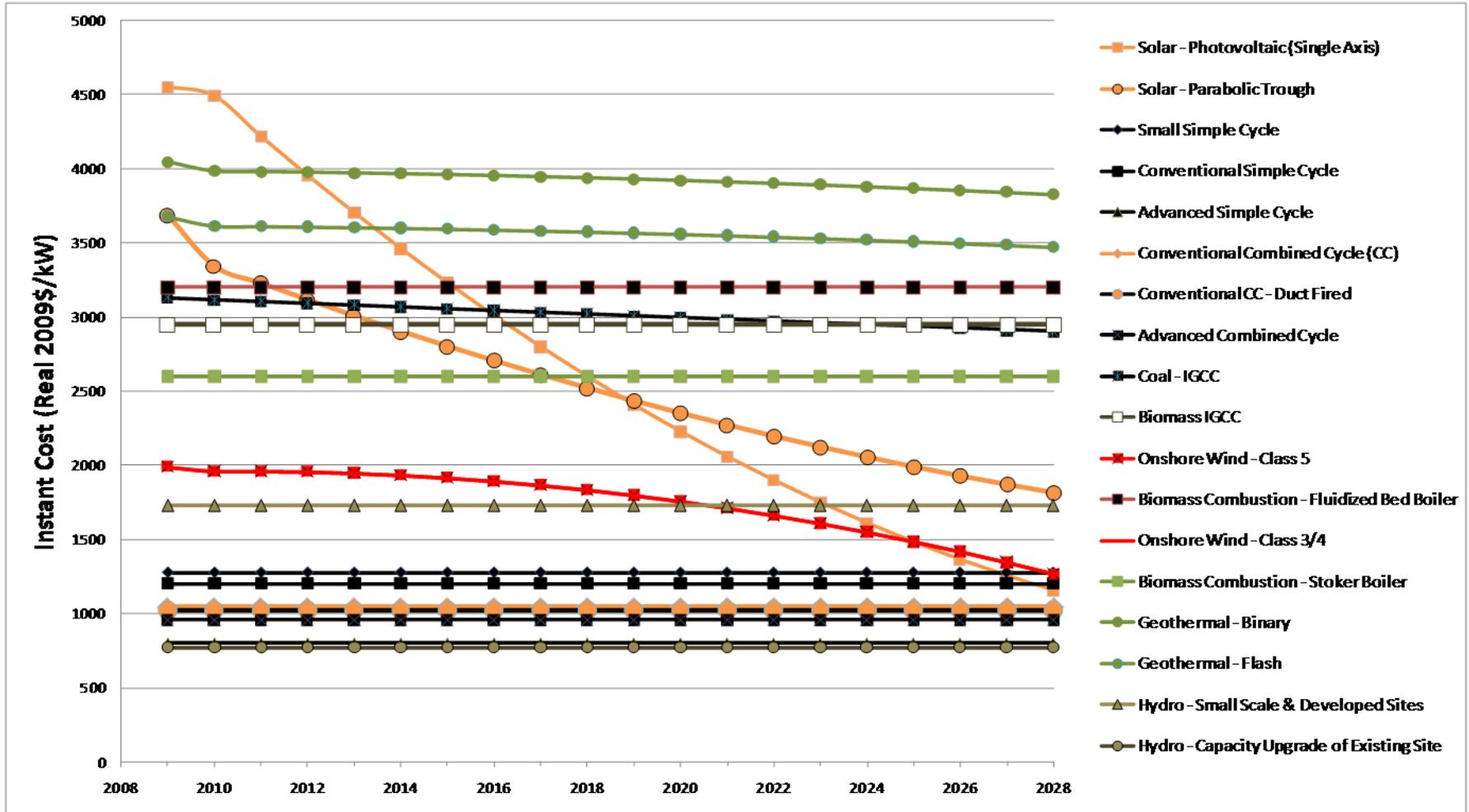


# DESIGN OBJECTIVES

- Large array of technologies in a single module
- Accommodate all types of developers
  - Merchant: Cash-Flow accounting
  - IOU & POU: Revenue Requirement accounting
- Multiple start-years to capture changing costs
- Point of measurement
  - Busbar plant
  - Busbar high side of transformer
  - Delivery point: Model transmission losses & costs



# INSTANT COSTS (in Real 2009\$)





# DESIGN OBJECTIVES – Cont.

- Levelized costs by geographical region
  - Fuel costs by utility
  - Air & water by basin - ERCs
- Enter capital costs as either instant or installed
- Calculate GHG adders and costs
- High-Low levelized costs
- Success rate in using tax credits



# INPUT SELECTION

<b>Plant Type Assumptions (Select)</b>	<b>Wind - Class 5</b>
<b>Financial (Ownership) Assumptions (Select)</b>	<b>Merchant Alternatives</b>
<b>Ownership Type For Scenarios</b>	<b>Merchant</b>
<b>General Assumptions (Select)</b>	<b>Default</b>
<b>Base Year (All Costs In 2009 Dollars)</b>	<b>2009</b>
<b>Fuel Type (Accept Default)</b>	<b>Wind</b>
<i>Data Source</i>	<i>KEMA 5-23-09</i>
<b>Start (Inservice) Year (Enter)</b>	<b>2011</b>
<b>Natural Gas Price Forecast (Select)</b>	<b>CA Average</b>
<b>Plant Site Region (Air &amp; Water) (Select)</b>	<b>CA - Avg.</b>
<b>Study Perspective (Select)</b>	<b>At Busbar - Plant Side</b>
<b>Reported Construction Cost Basis (Select)</b>	<b>Instant</b>
<b>Turbine Configuration (Select)</b>	<b>2</b>
<b>Carbon Price Forecast (Select)</b>	<b>No Carbon Price</b>
<b>Cost Scenario (Select)</b>	<b>Mid-range</b>
<b>Tax Loss Treatment (Select)</b>	<b>Loss Recovered in Single Year</b>



# OTHER DESIGN CRITERIA

- Ability to create, save, and recall scenarios
- Enter fuel costs year by year
- Plant, transformer, and transmission losses
- Capacity and heat rate degradation
- Start-up costs
- Combined Cycle unit heat rate as a function of capacity factor



# OUTPUTS

- Provide output data in all usable formats:
  - Levelized and annual
  - \$/kW-Year, \$/MWh, & cents/kWh
- Provide fixed and variable components levelized costs
- Provide mid, high, & low input data and levelized costs
- Macro to provide LCOEs for all technologies in a single run – otherwise, it's 378 separate runs (12,474 pieces of data)



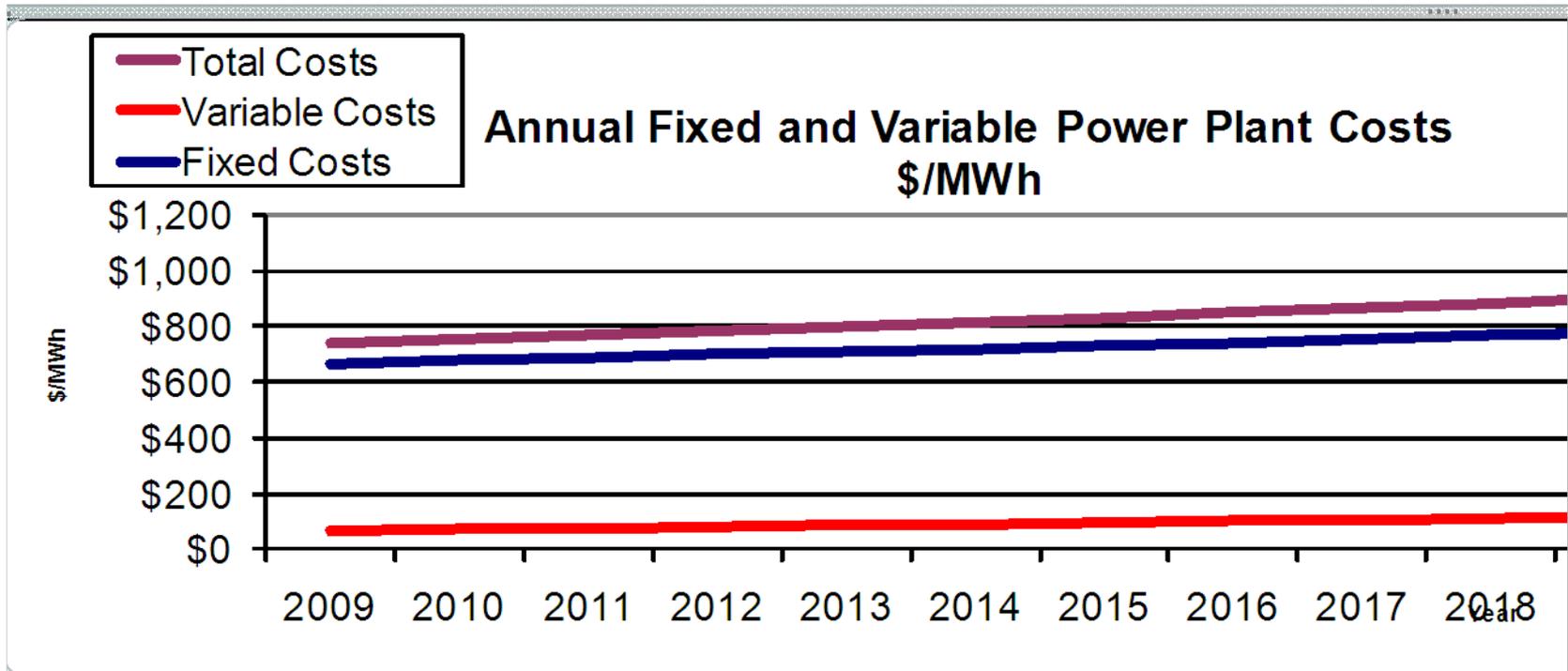
# LCOE OUTPUTS

## SUMMARY OF LEVELIZED COSTS Wind - Class 5

Start Year = 2011 (2011 Dollars)	\$/kW-Yr	\$/MWh
Capital & Financing - Construction	\$213.02	\$63.17
Insurance	\$15.78	\$4.68
Ad Valorem Costs	\$23.86	\$7.08
Fixed O&M	\$17.26	\$5.12
Corporate Taxes (w/Credits)	(\$103.28)	(\$30.63)
<b>Fixed Costs</b>	<b>\$166.64</b>	<b>\$49.42</b>
Fuel & GHG Emissions Costs	\$0.00	\$0.00
Variable O&M	\$23.13	\$6.86
<b>Variable Costs</b>	<b>\$23.13</b>	<b>\$6.86</b>
<b>Transmission Service Costs</b>	<b>\$0.00</b>	<b>\$0.00</b>
<b>Total Levelized Costs</b>	<b>\$189.77</b>	<b>\$56.28</b>



# ANNUAL COSTS



	Levelized	NPV	2009	2010	2011	2012	2013	2014	2015	2016	2017
<b>Fixed Costs</b>	<b>\$738</b>	<b>\$6,096</b>	<b>\$668</b>	<b>\$678</b>	<b>\$689</b>	<b>\$699</b>	<b>\$710</b>	<b>\$720</b>	<b>\$731</b>	<b>\$743</b>	<b>\$754</b>
<b>Variable Costs</b>	<b>\$101</b>	<b>\$831</b>	<b>\$69</b>	<b>\$73</b>	<b>\$77</b>	<b>\$82</b>	<b>\$87</b>	<b>\$91</b>	<b>\$94</b>	<b>\$101</b>	<b>\$106</b>
<b>Total Costs</b>	<b>\$844</b>	<b>\$6,967</b>	<b>\$742</b>	<b>\$756</b>	<b>\$770</b>	<b>\$786</b>	<b>\$801</b>	<b>\$816</b>	<b>\$830</b>	<b>\$848</b>	<b>\$866</b>



# ILLUSTRATIVE OUTPUT

## Merchant Plant in 2009 \$/MWh

In-Service Year = 2009 (Nominal 2009 \$)	Size MW	\$/MWh (Nominal \$)											¢/kWh
		Capital & Financing	Insurance	Ad Valorem	Fixed O&M	Taxes	Total Fixed Cost	Fuel	Variable O&M	Total Variable Cost	Transmission Cost	Total Levelized Cost	
Small Simple Cycle	49.9	482.17	23.44	31.87	66.81	134.18	738.46	95.54	5.08	100.62	5.24	844.31	84.43
Conventional Simple Cycle	100	459.43	22.33	30.36	48.56	128.14	688.82	95.54	5.08	100.62	5.24	794.67	79.47
Advanced Simple Cycle	200	158.70	7.71	10.49	22.79	44.28	243.98	88.15	4.47	92.62	5.24	341.84	34.18
Conventional Combined Cycle (CC)	500	28.64	1.38	1.88	1.61	9.42	42.93	72.05	3.66	75.71	5.21	123.84	12.38
Conventional CC - Duct Fired	550	30.26	1.46	1.99	1.67	9.95	45.32	73.19	3.66	76.85	5.21	127.38	12.74
Advanced Combined Cycle	800	25.91	1.25	1.70	1.34	8.52	38.73	67.17	3.26	70.43	5.21	114.36	11.44
Coal - IGCC	300	72.98	3.83	5.21	9.38	-11.33	80.08	19.38	11.98	31.36	5.38	116.83	11.68
Biomass IGCC	30	59.97	3.84	5.08	29.12	-26.40	71.62	26.75	5.08	31.84	6.54	109.99	11.00
Biomass Combustion - Fluidized Bed Boiler	28	60.92	3.78	5.00	17.56	-23.00	64.26	27.35	5.83	33.18	6.58	104.02	10.40
Biomass Combustion - Stoker Boiler	38	48.64	3.02	4.00	27.66	-18.49	64.83	28.06	8.91	36.97	6.45	108.25	10.83
Geothermal - Binary	15	84.76	6.52	9.85	11.15	-48.94	63.33	0.00	5.94	5.94	13.83	83.11	8.31
Geothermal - Flash	30	74.41	5.74	8.67	13.19	-43.22	58.79	0.00	6.61	6.61	13.51	78.91	7.89
Hydro - Small Scale & Developed Sites	15	93.65	7.03	10.62	11.10	-46.78	75.62	0.00	4.85	4.85	6.00	86.47	8.65
Hydro - Capacity Upgrade of Existing Site	80	43.98	2.97	4.48	7.53	-0.84	58.12	0.00	3.16	3.16	5.68	66.96	6.70
Solar - Parabolic Trough	250	257.53	16.58	0.00	47.03	-114.69	206.45	0.00	0.00	0.00	18.26	224.70	22.47
Solar - Photovoltaic (Single Axis)	25	317.91	20.47	0.00	47.03	-141.44	243.96	0.00	0.00	0.00	18.26	262.21	26.22
Onshore Wind - Class 3/4	50	74.66	5.53	8.36	5.90	-36.18	58.28	0.00	6.97	6.97	7.16	72.41	7.24
Onshore Wind - Class 5	100	65.77	4.87	7.37	5.20	-31.88	51.34	0.00	6.97	6.97	7.16	65.47	6.55



# ILLUSTRATIVE SUMMARY

## Average Plant Type Data

Technology - Plant Data	Gross Capacity (MW)	Plant Side Losses	Transformer Losses	Transmission Losses	Scheduled Outage Factor	Forced Outage Rate	Capacity Factor	HHV Heat Rate (Btu/kWh)	Degradation (%/Year)		Emission Factors (Lbs/MWh)					
									Capacity	Heat Rate	NOx	VOC	CO	CO2	SOx	PM10
Small Simple Cycle	49.9	3.40%	0.50%	2.09%	2.72%	5.56%	5.00%	9,266	0.05%	0.05%	0.279	0.054	0.368	1080.2	0.013	0.134
Conventional Simple Cycle	100	3.40%	0.50%	2.09%	3.18%	4.13%	5.00%	9,266	0.05%	0.05%	0.279	0.054	0.368	1080.2	0.013	0.134
Advanced Simple Cycle	200	3.40%	0.50%	2.09%	3.18%	4.13%	10.00%	8,550	0.05%	0.05%	0.099	0.031	0.190	996.7	0.008	0.062
Conventional Combined Cycle (CC)	500	2.90%	0.50%	2.09%	6.02%	2.24%	75.00%	6,940	0.20%	0.20%	0.070	0.208	0.024	814.9	0.005	0.037
Conventional CC - Duct Fired	550	2.90%	0.50%	2.09%	6.02%	2.24%	70.00%	7,050	0.20%	0.20%	0.076	0.315	0.018	825.4	0.009	0.042
Advanced Combined Cycle	800	2.90%	0.50%	2.09%	6.02%	2.24%	75.00%	6,470	0.20%	0.20%	0.064	0.018	0.056	758.9	0.005	0.031
Coal - IGCC	300	6.00%	0.50%	2.09%	15.00%	5.00%	80.00%	7,580	0.05%	0.10%	0.220	0.009	0.079	153.2	0.063	0.031
Biomass IGCC	30	3.50%	0.50%	5.00%	3.00%	8.00%	75.00%	10,500	0.05%	0.20%	0.074	0.009	0.029	N/A	0.020	0.100
Biomass Combustion - Fluidized Bed Boiler	28	6.00%	0.50%	5.00%	3.00%	8.00%	85.00%	10,500	0.10%	0.15%	0.074	0.009	0.079	N/A	0.020	0.100
Biomass Combustion - Stoker Boiler	38	4.00%	0.50%	5.00%	3.00%	8.00%	85.00%	11,000	0.10%	0.15%	0.075	0.012	0.105	N/A	0.034	0.100
Geothermal - Binary	15	5.00%	0.50%	5.00%	4.00%	2.50%	90.00%	N/A	4.00%	N/A	0.000	0.000	0.000	N/A	N/A	N/A
Geothermal - Flash	30	5.00%	0.50%	5.00%	4.00%	2.50%	94.00%	N/A	4.00%	N/A	0.191	0.011	0.058	N/A	0.026	0.000
Hydro - Small Scale & Developed Sites	15	10.00%	0.50%	5.00%	9.40%	5.10%	30.40%	N/A	2.00%	N/A	0.000	0.000	0.000	N/A	N/A	N/A
Hydro - Capacity Upgrade of Existing Site	80	5.00%	0.50%	5.00%	9.40%	5.10%	30.40%	N/A	2.00%	N/A	0.000	0.000	0.000	N/A	N/A	N/A
Solar - Parabolic Trough	250	22.40%	0.50%	5.00%	2.20%	1.60%	27.00%	N/A	0.50%	N/A	0.000	0.000	0.000	N/A	N/A	N/A
Solar - Photovoltaic (Single Axis)	25	22.40%	0.50%	5.00%	0.00%	2.00%	27.00%	N/A	0.50%	N/A	0.000	0.000	0.000	N/A	N/A	N/A
Onshore Wind - Class 3/4	50	0.10%	0.50%	5.00%	1.39%	2.00%	37.00%	N/A	1.00%	N/A	0.000	0.000	0.000	N/A	N/A	N/A
Onshore Wind - Class 5	100	0.10%	0.50%	5.00%	1.39%	2.00%	42.00%	N/A	1.00%	N/A	0.000	0.000	0.000	N/A	N/A	N/A



# ILLUSTRATIVE SUMMARY

## Average Plant Cost Data

Plant Cost Data Start Year = 2009 (2009 Dollars)	Gross Capacity (MW)	Instant Costs (\$/kW)			Construction Period (%/Year)						Fixed O&M (\$/kW-Yr)	Variable O&M (\$/MWh)
		Base	Environmental Compliance	Total	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5		
Small Simple Cycle	49.9	1,277	15	1,292	100%	0%	0%	0%	0%	0%	23.94	4.17
Conventional Simple Cycle	100	1,204	27	1,231	100%	0%	0%	0%	0%	0%	17.40	4.17
Advanced Simple Cycle	200	801	26	827	75%	25%	0%	0%	0%	0%	16.33	3.67
Conventional Combined Cycle (CC)	500	1,044	51	1,095	75%	25%	0%	0%	0%	0%	8.62	3.02
Conventional CC - Duct Fired	550	1,021	59	1,080	75%	25%	0%	0%	0%	0%	8.30	3.02
Advanced Combined Cycle	800	957	33	990	75%	25%	0%	0%	0%	0%	7.17	2.69
Coal - IGCC	300	3,128	56	3,184	80%	20%	0%	0%	0%	0%	52.35	9.57
Biomass IGCC	30	2,950	47	2,997	75%	25%	0%	0%	0%	0%	150.00	4.00
Biomass Combustion - Fluidized Bed Boiler	28	3,200	54	3,254	80%	20%	0%	0%	0%	0%	99.50	4.47
Biomass Combustion - Stoker Boiler	38	2,600	58	2,658	80%	20%	0%	0%	0%	0%	160.10	6.98
Geothermal - Binary	15	4,046	0	4,046	40%	40%	20%	0%	0%	0%	47.44	4.55
Geothermal - Flash	30	3,676	42	3,718	40%	40%	20%	0%	0%	0%	58.38	5.06
Hydro - Small Scale & Developed Sites	15	1,730	0	1,730	100%	0%	0%	0%	0%	0%	17.57	3.48
Hydro - Capacity Upgrade of Existing Site	80	771	0	771	100%	0%	0%	0%	0%	0%	12.59	2.39
Solar - Parabolic Trough	250	3,687	0	3,687	100%	0%	0%	0%	0%	0%	68.00	0.00
Solar - Photovoltaic (Single Axis)	25	4,550	0	4,550	100%	0%	0%	0%	0%	0%	68.00	0.00
Onshore Wind - Class 3/4	50	1,990	0	1,990	95%	5%	0%	0%	0%	0%	13.70	5.50
Onshore Wind - Class 5	100	1,990	0	1,990	95%	5%	0%	0%	0%	0%	13.70	5.50

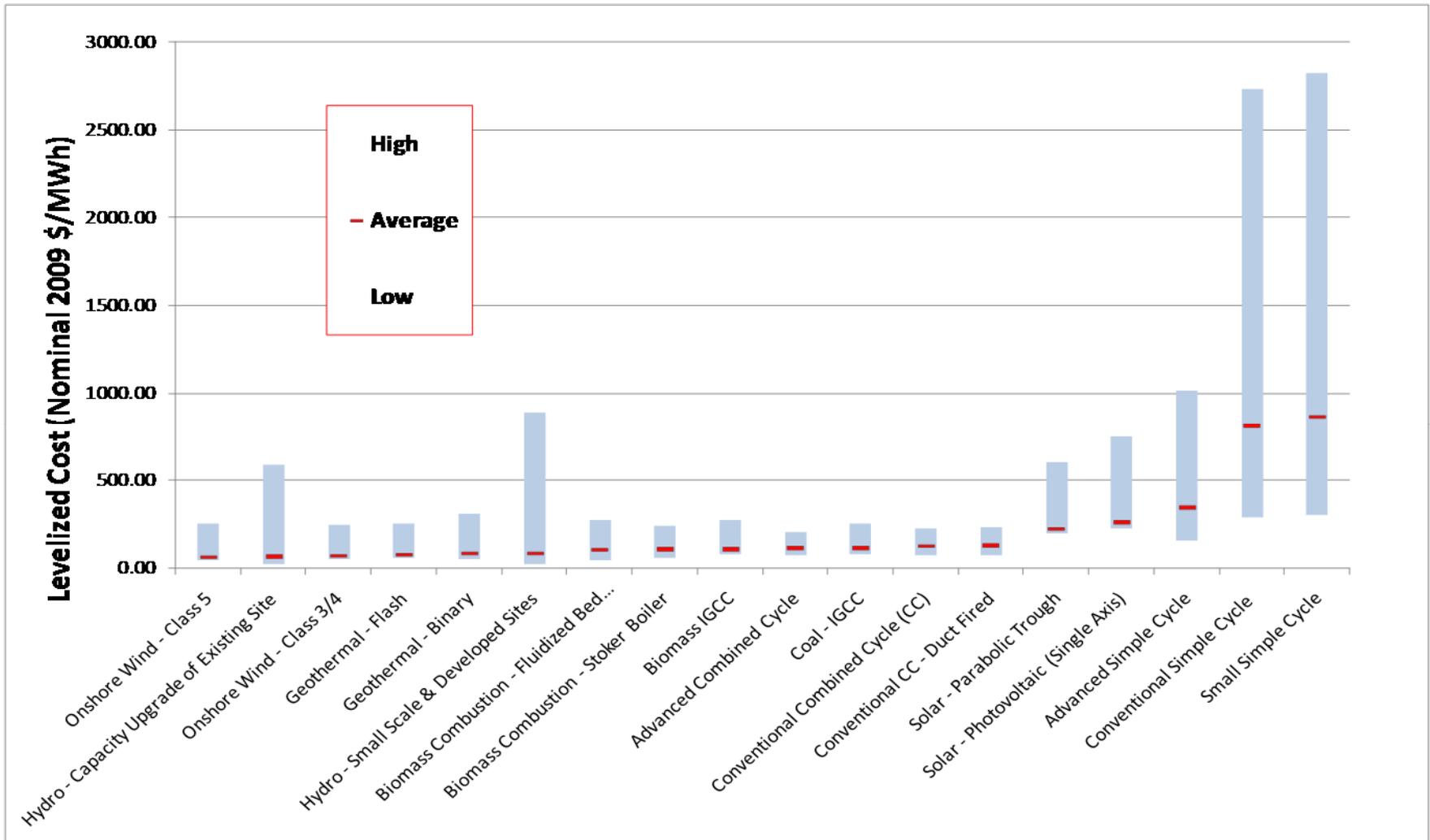


# AVOIDING MISUSE OF DATA

- Common misunderstandings
  - One size fits all – actual LCOEs vary over a wide range: So we provide high-low cost range
  - Most common error is ignoring the effect of capacity factor; Provide screening curves
  - LCOEs do not speak to the effect of the technology on the system or how the technology will actually function in the system
  - Price does not equal cost

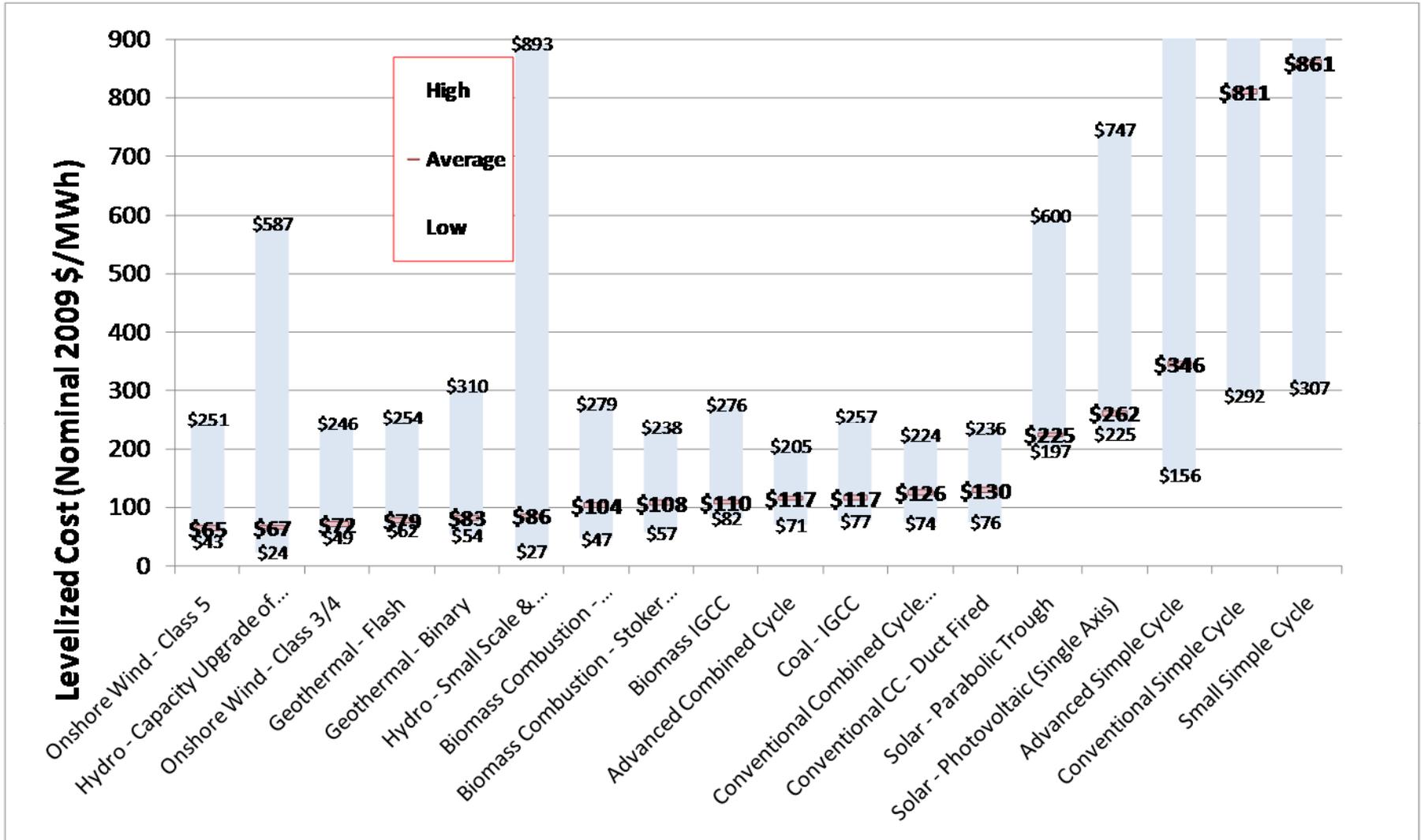


# Range of Levelized Cost Merchant Plant In-Service in 2009



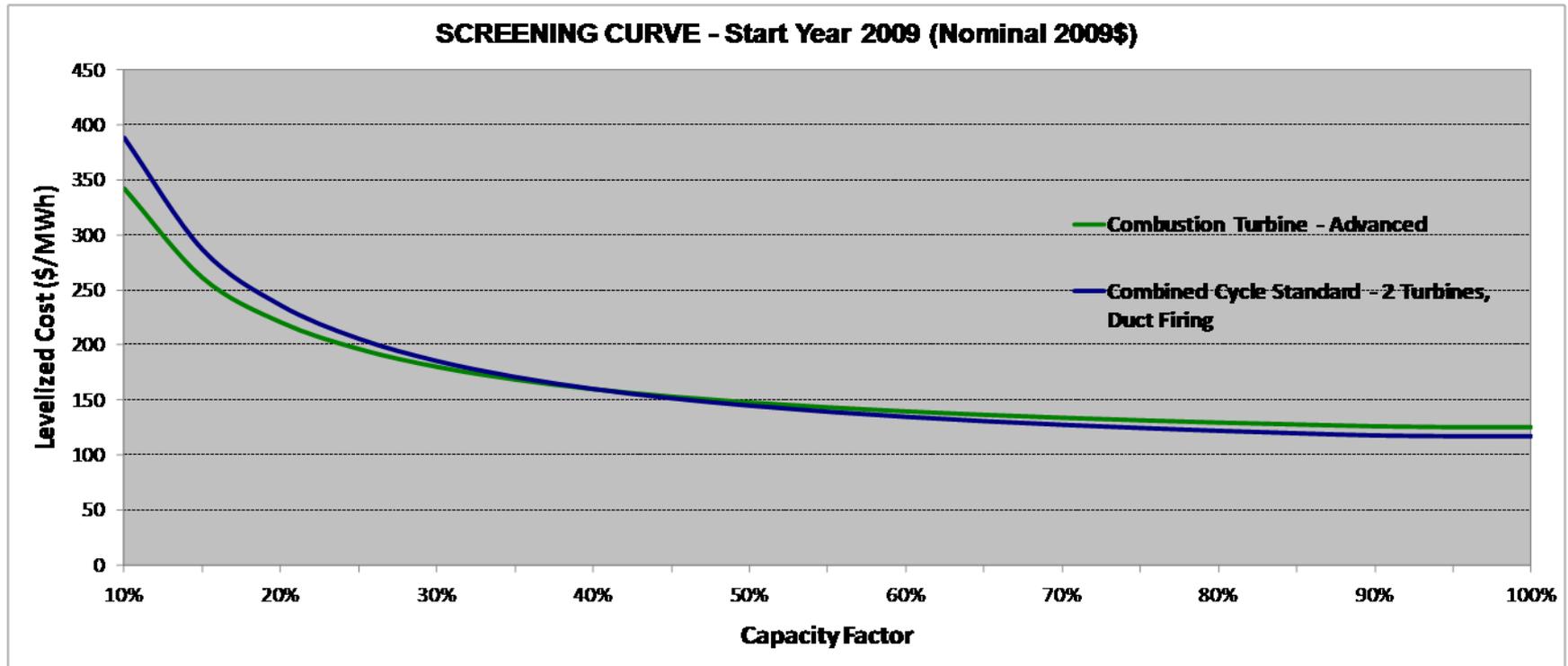


# 2009 EXPANDED





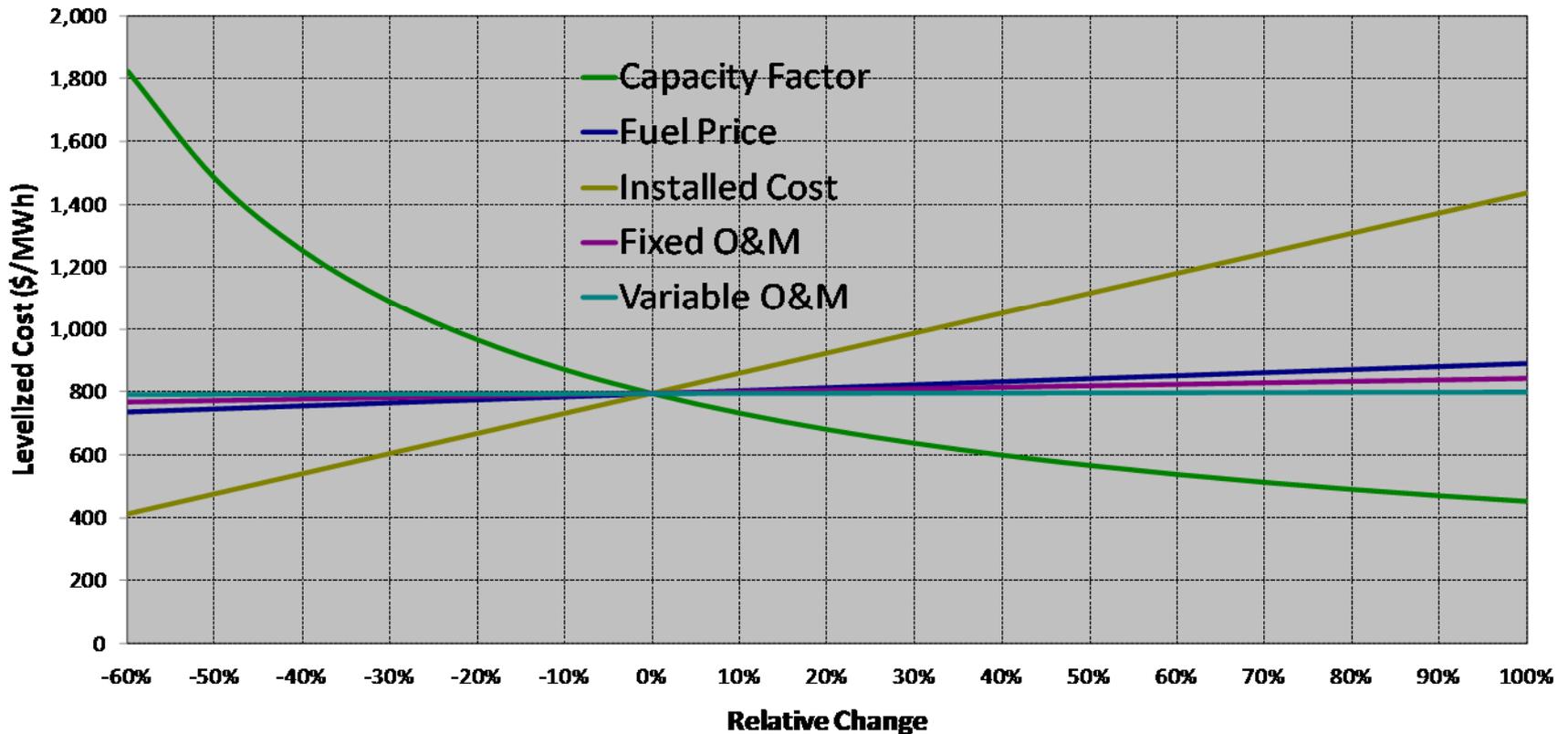
# SCREENING CURVES





# SENSITIVITY CURVES

Effect on Levelized Cost of Input Assumptions  
Start Year 2009 (Nominal 2009\$)  
Combustion Turbine - 100 MW





### Plant Characteristics

- Gross Capacity (MW)
- Plant Side Losses
- Transformer Losses
- Transmission Losses
- Forced Outage Rate
- Scheduled Outage Rate
  - Capacity Factors
- Heat Rate (if applicable)
- Heat Rate Degradation
- Capacity Degradation
- Emission Factors

### General Assumptions

- (Merchant, Muni & IOU)
- Insurance
    - O&M Escalation
    - Labor Escalation

Deflator Series

## **COST OF GENERATION MODEL**

### Plant Cost Data

- Instant Cost (\$/kW)
- Installed Cost (\$/kW)
- Construction Period (Yrs)
  - Fixed O&M (\$/kW)
  - Variable O&M (\$/MWh)

### Financial Assumptions

(Merchant, Muni & IOU)

- % Debt
  - Cost of Debt (%)
  - Cost of Equity (%)
- Loan/Debt Term (Years)
- Econ/Book Life (Years)

### Fuel Cost

- Fuel Cost (\$/MMBtu)
- Heat Rate (Btu/kWh)

### Tax Information

(Merchant & IOU)

- Federal Tax Rate (%)
- State Tax Rate (%)
- Federal Tax Life (Years)
- State Tax Life (Years)
  - Tax Credits
- Ad Valorem Tax
- Sales Tax



# QUALITY DATA

- Renewables, Nuclear & IGCC/Coal
  - 2007 IEPR: Consultant NCI
  - 2009 IEPR: Consultant KEMA
- Gas-Fired Data (Aspen)
  - 2007 IEPR: Survey of Developers 2001-06
  - 2009 IEPR: Compared Survey data against various publically available data and adjusted cost data for unusual real inflation
- Financial Variables: Aspen using BOE data



# FEDERAL TAX BENEFITS

- Accelerated Depreciation on Federal taxes (5 Years)
- Tax Deduction for Manufacturing Activities (TDMA)
- Property Tax Exemption for Solar Systems
- Geothermal Depletion Allowance (GDA)
- Renewable Electricity Production Tax Credit (PTC)
- Business Energy Investment Tax Credit (ITC)
- America Recovery and Investment Act (ARRA)
  - Makes PTC technologies eligible for ITC (Expire 2013-16)
  - Allow PTC/ITC technologies to expense in first year.



# NEW TAX BENEFITS NOT COVERED IN CEC 2009 IEPR

- Tax benefits that became active after the completion of the 2009 IEPR
  - Sales Tax exemption
  - 100 percent depreciation (2010)



# DOCUMENTATION

- Within the Model – Data sources and calculation mechanisms as Excel comments
- Outside the Model – User's Guide (114 pages)
  - Describe Model – worksheet by worksheet
  - Delineate algorithms
  - Instructions on the use the Model
  - An appendix of definitions (23 pages)



**END**