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Renewable Energy Cost Drivers

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Outline

Cost variability and change

Cost drivers:

- – Definition
- – Project activity
- – Project funding

- Cost analysis:
  - – Progress this year
  - – Future needs
- Questions

April 16th Summary

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- Deployment to date:
  - Utility scale – substantial base plus project development
  - Community scale – pilot projects and regulatory barriers
  - Building scale – PV approaching energy significant phase
- RE resource and technology base – diversity and endless variation
- Consultant study is designed to:
  - Improve cost baselines used in biennial analysis
  - Bridge to more comprehensive analysis addressing value/cost relationships and total system cost vs. plant cost

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- Initiate in-depth future-oriented cost analysis
  - Focus on major contributors to least-cost future mix
  - Understand global market trends and dynamics
- Modeling of integrated energy system cost
  - Renewable energy supply contributions at all levels
  - Natural gas as an enabler vs. alternative
  - Whole system optimization capability

Multiple moving targets

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Renewable energy cost analysis must account for resource, technology, applications, technology and industry maturity and scale diversity, all of which drive project finance diversity.

√ = primary application	Deployment Venues		
√ = secondary application	Utility-Scale Renewables	RE Secure Communities	RE Secure Buildings
Technology/ Resource	Utility-scale power plants and bio-refineries	Smaller energy plants exploiting high-quality local resources	Modular systems for building and industrial power, heat, cooling and lighting
Wind Power Plants	**√**	**√**	
Geothermal Power	**√**	√	
Hi Temp Solar Thermal	**√**	√	√
Biomass Power	√	**√**	√
Ocean/Wave	√	**√**	
Solar PV	√	**√**	**√**
DG Wind		√	**√**
Solar Heat & Cooling		√	**√**
Direct Geothermal		**√**	√
Geothermal Heat Pumps		√	**√**
Biofuels	**√**	√	√

What is a cost driver?

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The basic questions of renewable energy deployment, i.e. when and how much, hinge on forecasts of future costs, hence on the factors that will drive cost evolution.

- In activity based costing (which states that products consume activities and activities consume resources) a cost driver is any factor which causes a change in the cost of an activity.

Source: BusinessDictionary.com

- Production of electricity is an activity that consumes resources.

Energy Supply Cost Drivers

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Experience enables - and competition drives - energy capture/conversion improvements, scale-up, and value/cost innovation.

- Experience
  - Engineering
  - Procurement
  - Construction
- Competition
- Energy — Examples:
  - Capture__________________________geothermal
  - Conversion ______________________biomass
- Scale
  - Plant ____________________________solar thermal
  - Equipment _______________________wind
  - Manufacturing ____________________solar PV
- Value/Cost Innovation_________high temperature storage

Commercial Technology Menu

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Relatively accurate current cost assumptions can be developed for options in commercial use. Project scale matters.

KEMA Task 1 scope:

- Recommend RE technologies for detailed analysis:
  - **Utility** scale (>20MW)
  - **Community** scale (1-20MW)
  - **Building** scale (<1MW)
- Identify primary commercial embodiment of commercially deployed options…

2009 Menu

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Differentiating according to scale and commercial experience significantly shortened the utility scale renewables menu.

- Added to options commercially deployed at scale:
  - Solar thermal with high temperature storage
  - Biomass co-firing
  - Hydro capacity upgrade
  - Class 5 wind
- Potential future menu additions:
  - High concentration solar thermal and PV
  - Deep water wind
  - Wave
  - IGCC
  - Nuclear

Utility-scale RE Menu

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Technology List	Gross Capacity (MW)	Data Start Date
Biomass		
Biomass Combustion - Fluidized Bed Boiler	28	Current
Biomass Combustion - Stoker Boiler	38	Current
Biomass Cofiring	20	Current
Biomass Co-Gasification IGCC	30	2018
Geothermal		
Geothermal - Binary	15	Current
Geothermal - Flash	30	Current
Hydropower		
Hydro - Small Scale (developed sites without power)	15	Current
Hydro - Capacity upgrade for developed sites with power	80	Current
Solar		
Solar - Parabolic Trough	250	Current
Solar - Photovoltaic (Single Axis)	25	Current
Wind		
Onshore Wind - Class 5	100	Current
Onshore Wind - Class 3/4	50	Current
Offshore Wind - Class 5	100	2018
Wave		
Ocean Wave	40	2018

Cost Build-up

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In Task 2 KEMA identified as cost drivers a mix of important cost elements and influences

Cost Drivers

Key Cost Drivers

- Site geographies
- Turbine Island
- Exploration
- Confirmation Drilling
- Steam gathering
- Royalties
- O&M

Geothermal Flash

Cost Drivers

Key Cost Drivers

- PV Module costs
- Silicon Production capacity
- New manufacturing Capacity
- Land acquisition
- Fixed O&M

Solar PV

Current costs and ranges

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In Task 3 KEMA identified plausible average, minimum and maximum current costs for each renewable energy grouping

Technology Name: Biomass - Stoker Boiler

All costs are in 2000 nominal dollars unless otherwise noted.

Year=2009, Value & Dollars			
PLANT DATA	**Average**	**High**	**Low**
Gross Capacity (MW)	38	25	50
Station Service (%)	4.00%	7.00%	2.40%
Net Capacity (MW)	36.48	23.25	48.80
Net Energy (GWh)	272	153	385
Transformer Losses	0.50%	0.50%	0.50%
Tranmission losses	5.00%	5.00%	5.00%
Load Center Delivered Capacity (MW)	34.48	21.98	46.13
Net Capacity Factor (NCF)	85.00%	75.00%	90.00%
Planned Percent of Year Operational	92.39%	88.65%	97.70%
Average Percent Output	100.0%	100.0%	100.0%
Net Energy Delivered to Load Center (GWh)	256.76	144.39	363.67
Forced Outage Rate (FOR)	8.00%	10.00%	6.00%
Scheduled Outage Factor (SOF)	3.00%	6.00%	2.00%

Progress ratios

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In Task 4 KEMA used Task 3 information to assess the weighted impact of each cost driver and determine a weighted average progress ratios for each technology grouping.

Table 2. Cost Driver Analysis Worksheet Example

Cost Driver Analysis

Technology: **Onshore Wind** 7

Technology Progress Ratio: **0.900**

			Rate of Change		
	Cost Driver	**Percentage**	**Low**	**Average**	**High**
1	Turbine Costs	75.0%	0.95	1.00	1.10
2	Reliability	10.0%	0.97	1.00	1.04
3	Permitting/Site Selection	5.0%	0.98	1.00	1.02
4	Land Acquisition	5.0%	0.99	1.00	1.01
5	Transmission Costs	5.0%	0.97	1.00	1.10
	Total and Averages:	**100.0%**	**0.96**	**1.00**	**1.09**
	Modified Progress Ratio:		0.86	0.90	0.98

Cost trajectories

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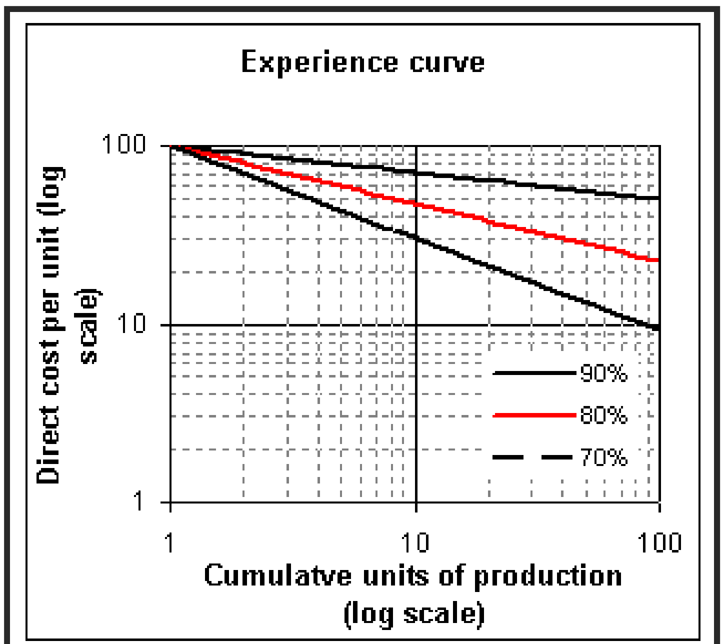
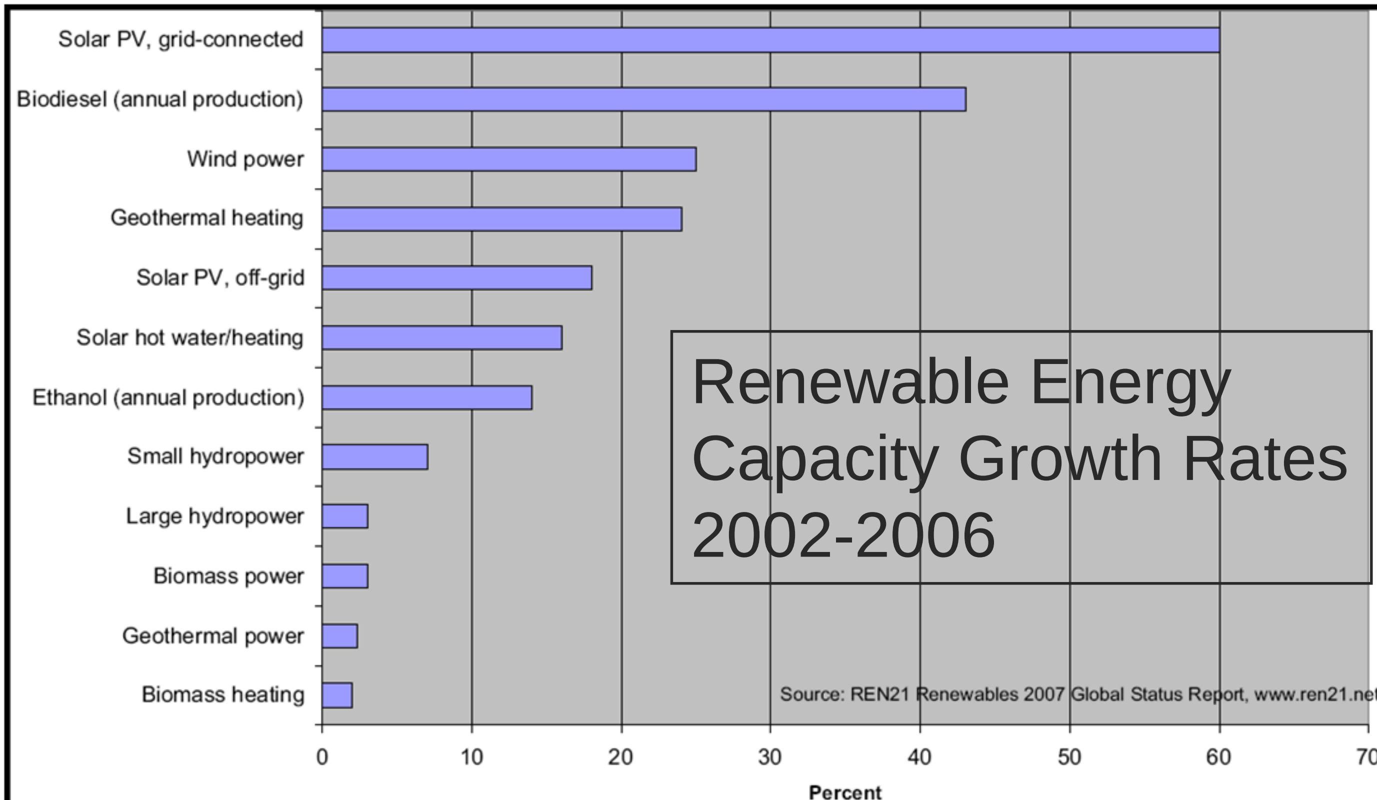
In completing Task 4 KEMA used estimates of future installed capacity and modified progress ratios in the standard experience curve formula to adjust forecasted yearly costs.

$$Cost\_Ratio \equiv \left[\frac{Cumulative\_Generation_Y}{Cumulative\_Generation_{Y-1}} \right] \wedge \ln\left(\frac{Modified\_Progress\_Ratio}{2} \right)$$



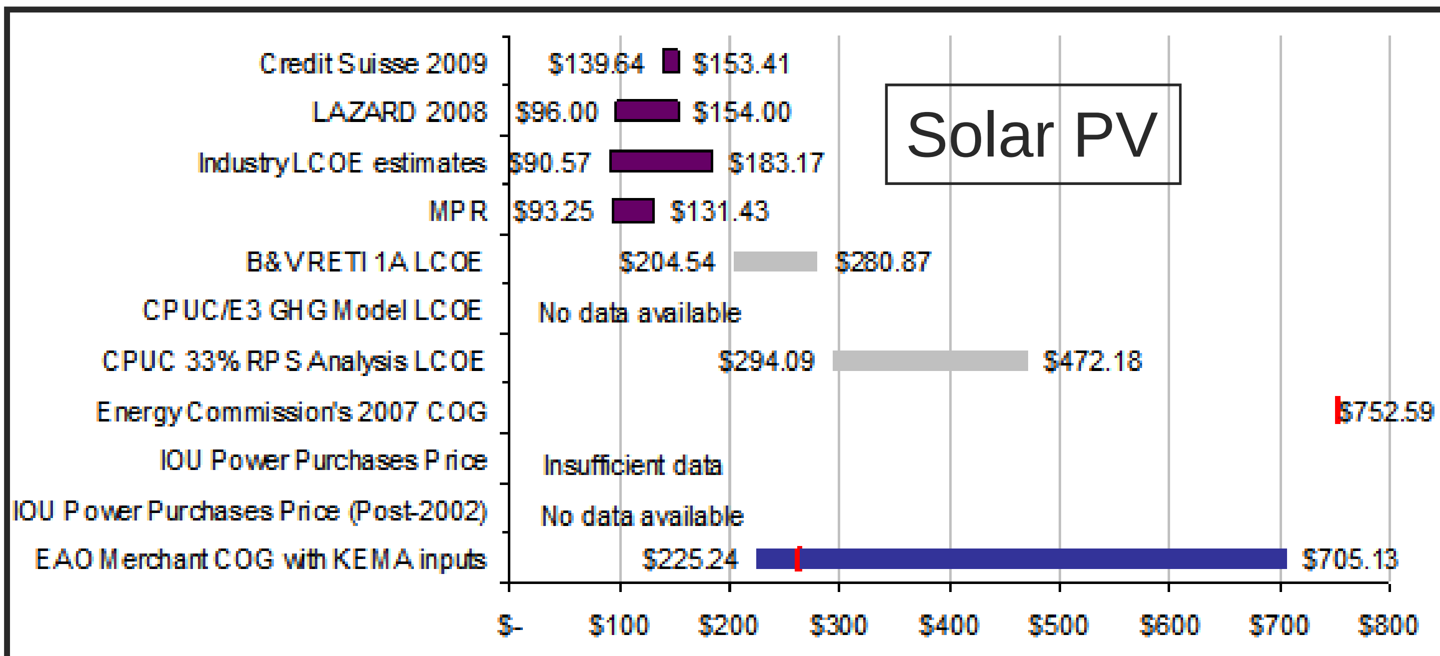
Capacity trajectories

The expected relative effect of experience on future costs can be inferred from renewable energy capacity data. Fast growing renewable energy industries are likely to achieve faster cost reduction than more stable and slower growing counterparts.



ation

KEMA's Task 5 included efforts to validate estimates of current costs based on consistency with market pricing and other benchmarks. Only indirect indications of market pricing were obtained; other comparisons suggest a need for confirmation that the Commission's LCOE cost and financing assumptions accurately represent successful projects in each major industry.



Project Scale

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Project scale economies for major technology groupings were not explicitly identified.

- Community and Building Scale cost analysis results (Task 6) coming up in the afternoon.
- Tasks 5 and 6 will be included in a PIER final report.
- Tasks 1 through 4 are included in a draft interim PIER report.
- Comparison of building, community and utility scale results for could yield better understanding of project scale as a cost driver.

LCOE Drivers

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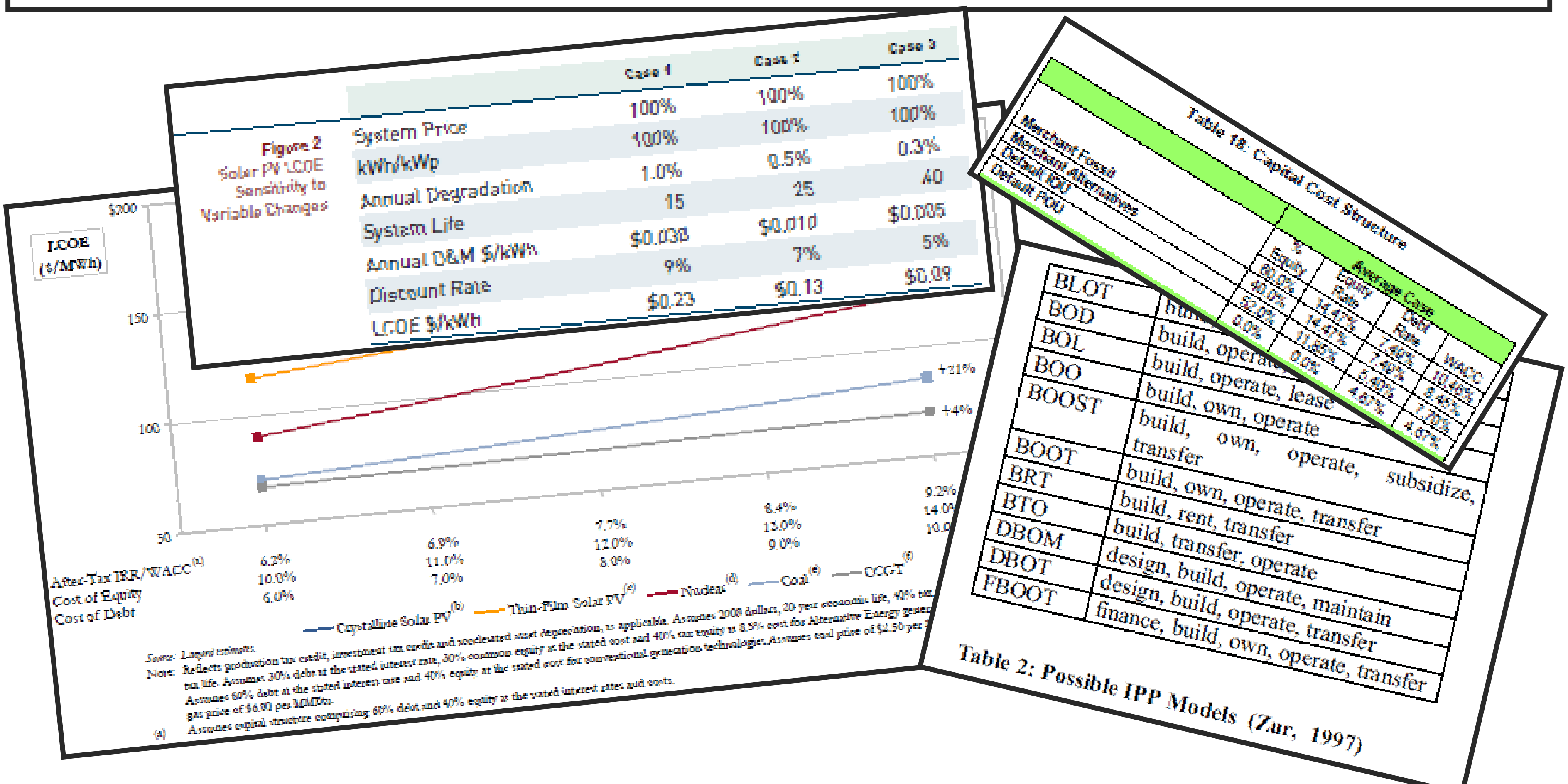
Debt and equity costs were impacted by financial melt-down, recession, and stimulus legislation; LCOE impacts are strongly driven by volatile and industry-specific weighted average costs.



	Case 1	Case 2	Case 3
System Price	100%	100%	100%
kWh/kWp	100%	100%	100%
Annual Degradation	1.0%	0.5%	0.3%
System Life	15	25	40
Annual O&M $/kWh	$0.030	$0.010	$0.005
Discount Rate	9%	7%	5%
LCOE $/kWh	$0.23	$0.13	$0.09

Table 18: Capital Cost Structure

	Average Case % Equity	Equity Rate	Debt Rate	WACC
Merchant Fossil	60.0%	14.47%	7.49%	10.46%
Merchant Alternatives	40.0%	14.47%	7.49%	8.45%
Default IOU	50.0%	11.85%	5.40%	7.70%
Default POU	0.0%	0.0%	4.67%	4.67%

BLOT	bu
BOD	build, opera
BOL	build, operate, lease
BOO	build, own, operate
BOOST	build, own, operate, subsidize, transfer
BOOT	build, own, operate, transfer
BRT	build, rent, transfer
BTO	build, transfer, operate
DBOM	design, build, operate, maintain
DBOT	design, build, operate, transfer
FBOOT	finance, build, own, operate, transfer

Table 2: Possible IPP Models (Zur, 1997)

Progress

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- Focus on options where cost experience can inform estimates
- Identification of emerging options to monitor
- Scale of representative projects reflects market
- Recognition of the full renewable energy menu from building to utility scale
- Cost ranges from technology specific cost build-up
- Use of experience curves to assess future costs
- Costs for renewable heating and cooling
- Reference to other recent cost studies and pricing benchmarks

Future Needs

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- Better cost build-up accuracy for high penetration renewable options at all deployment scales
- Attention to project value and annual electricity system delivered energy cost vs. undifferentiated project kWh cost
- Identify and account for project finance model variations among major renewable energy technology groupings
- Identify competitive project cost ranges
- Cost forecasting:
  - More consistent forecasting model “cost driver” definition
  - Further refinement of cost forecasting model
  - Validate progress ratios for high growth industries
  - Refine and validate community and building scale project costs
  - Address storage-coupled variable renewable energy projects

Questions

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- Need for organized on-going monitoring of renewable energy industry progress and project costs?
- Need to monitor/forecast changes in weighted average cost of capital for renewable energy projects?
- Expand efforts to validate LCOE modeling results?
- Does LCOE of fuel based options have a tighter range of variability than commercially active renewable energy options?
- Possible to address cost and value of variable renewable sources in an integrated way?
- How best to secure review of cost assumptions and model results by active market participants?

Thank you!

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April 16th presentation addressing renewable energy cost drivers and cost variability

2009 Integrated Energy Policy Report Staff Workshop

FUTURE ENERGY SUPPLY COSTS: MULTIPLE MOVING TARGETS

April 16, 2009

Gerry Braun
Technical Consultant
California Energy Commission

Outline

Presentation purpose: Provide market and technology context for renewable energy cost data

- Renewable Energy Options
  - Scale
  - Readiness
  - Diversity
- Cost Data Development
  - Research Context
  - Study Design

Issues

- Cost estimation in the context of:
  - fast changing cost drivers
  - proliferating options
- Metrics and methods for evaluating:
  - variable resources
  - community- and building-scale options

Renewable Energy Technology Menu

√ = primary application √ = secondary application	Deployment Venues		
	Utility-Scale Renewables	RE Secure Communities	RE Secure Buildings
Technology/ Resource	Utility-scale power plants and bio-refineries	Smaller energy plants exploiting high-quality local resources	Modular systems for building and industrial power, heat, cooling and lighting
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Geothermal Power	**√**	√	
Hi Temp Solar Thermal	**√**	√	√
Biomass Power	√	**√**	√
Ocean/Wave	√	**√**	
Solar PV	√	**√**	**√**
DG Wind		√	**√**
Solar Heat & Cooling		√	**√**
Direct Geothermal		**√**	√
Geothermal Heat Pumps		√	**√**
Biofuels	**√**	√	√

Commercial vs. Emerging – Technology Perspective

C = Commercial	Deployment Venues		
E = Emerging	Utility-Scale Renewables	RE Secure Communities	RE Secure Buildings
Technology/ Resource	Utility-scale power plants and bio-refineries	Smaller energy plants exploiting high-quality local resources	Modular systems for building and industrial power, heat, cooling and lighting
Wind Power Plants	C	C	
Geothermal Power	C	C	
Hi Temp Solar Thermal	C/E	C/E	E
Biomass Power/CHP	C	C	C
Ocean/Wave	E	E	
Solar PV	E	C/E	C
DG Wind		C/E	C/E
Solar Heat & Cooling		C/E	C/E
Direct Geothermal		C	C
Geothermal Heat Pumps		C	C
Cellulosic Biofuels	E	E	E

Commercial vs. Emerging – California Industry Capability Perspective

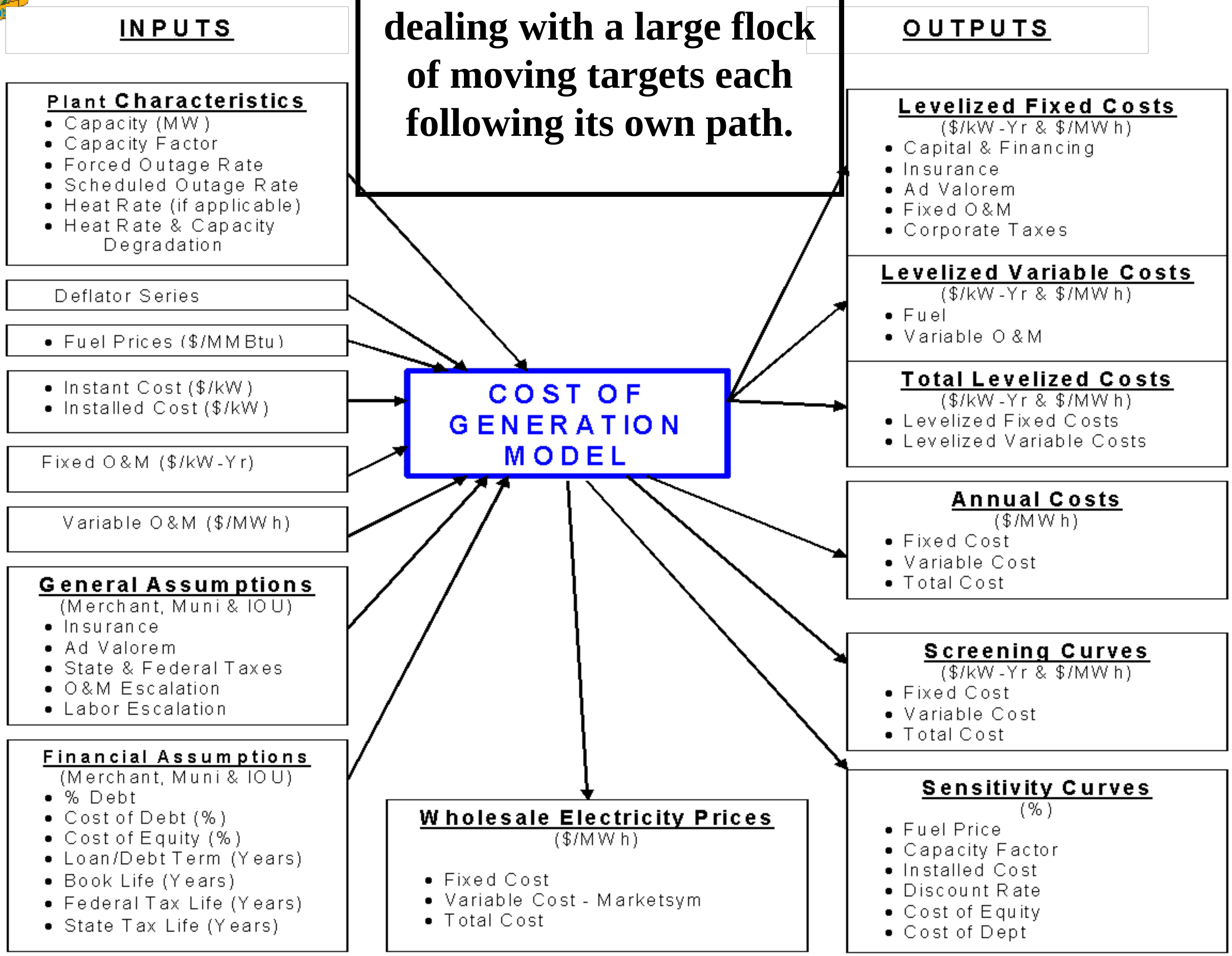
C = Capable	Deployment Venues		
D = Developing	Utility-Scale Renewables	RE Secure Communities	RE Secure Buildings
Technology/ Resource	Utility-scale power plants and bio-refineries	Smaller energy plants exploiting high-quality local resources	Modular systems for building and industrial power, heat, cooling and lighting
Wind Power Plants	C	D	
Geothermal Power	C	D	
Hi Temp Solar Thermal	C/D	D	D
Biomass Power/CHP	D	C/D	D
Ocean/Wave	D	D	
Solar PV	D	C	C
DG Wind		D	D
Solar Heat & Cooling		D	D
Direct Geothermal		D	D
Geothermal Heat Pumps		D	D
Cellulosic Biofuels	D	D	D

Dimensions of Diversity

- Resource
  - Quality
  - Location
- Resource Conversion Technology
  - Resource conversion technique
  - Variations on basic technique
  - Conversion efficiency/Energy Capture
  - Enabling technologies
- End Product or Service
  - Electricity, fuel, heat, etc.
  - Hybrid systems
- Equipment
  - Manufacturing scale
  - Materials price
  - Global market dynamics
- Plant
  - Scale
  - Functionality
  - Equipment modularity
- Economic
  - Customer requirements
  - Avoided cost
  - Finance model
  - Tax
- Deployment Experience
  - Industry Strength and Maturity
  - Standardization

New ball game – extremely diverse menu of renewable energy solutions that vary in several dimensions, affecting cost, price, risk and economic value.

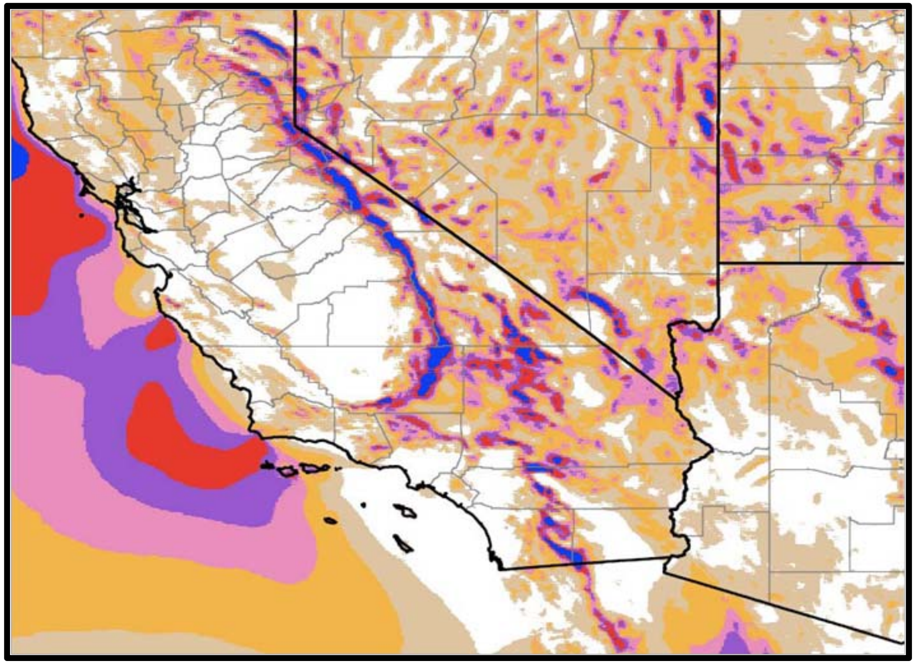
The challenge of COG data development is dealing with a large flock of moving targets each following its own path.



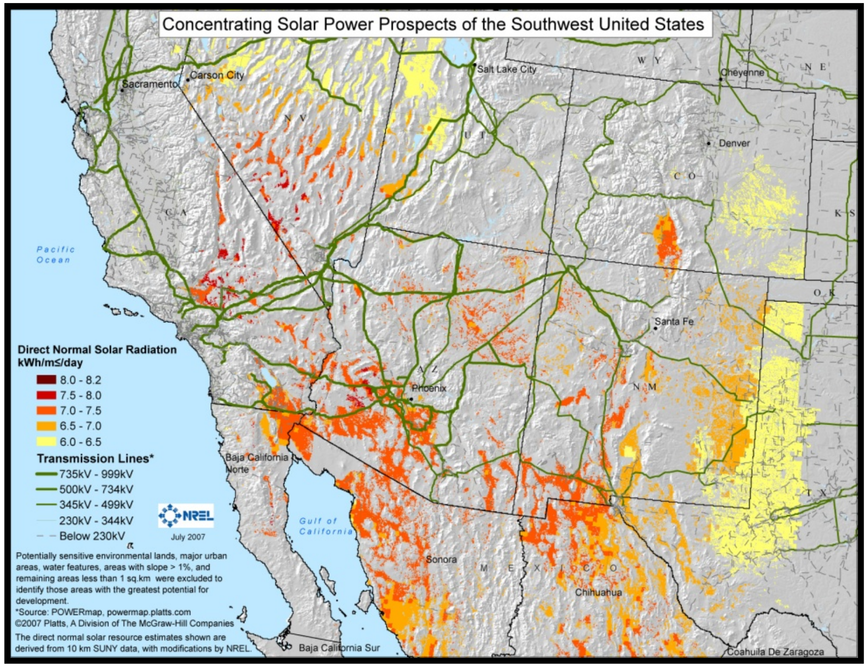
Resource Quality

Average annual resource intensity is an indicator, not an answer. Local resources vary and in some cases may change as the resource is used, e.g. geothermal.

Wind

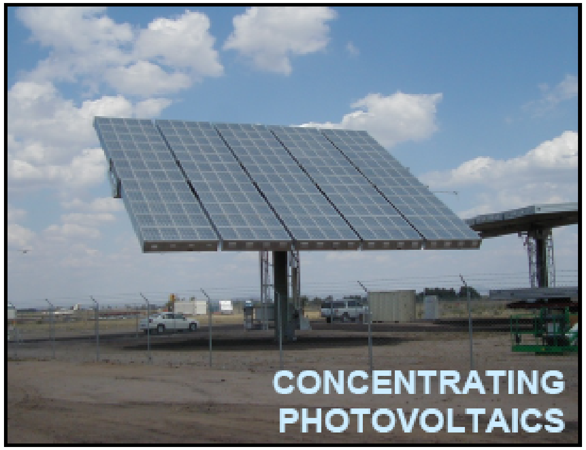


Concentrating Solar



Technology – Variations

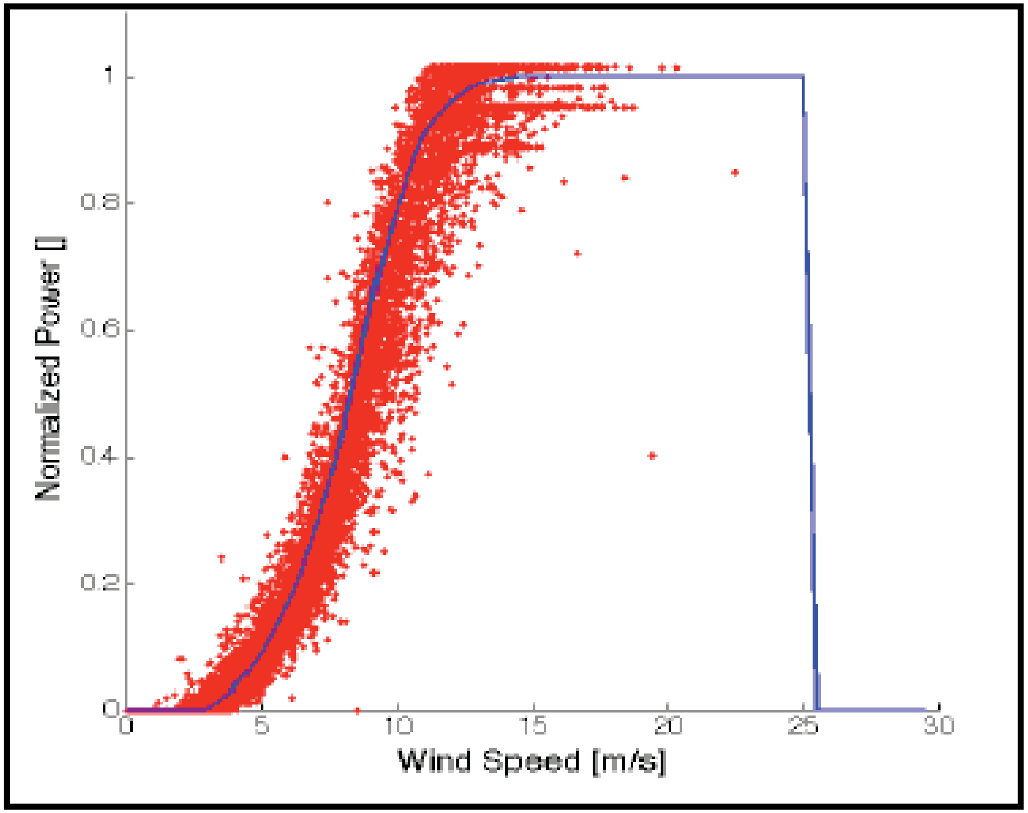
Concentrating solar power system concepts illustrate significant variations in conversion efficiency, scale-up risk, commercial readiness, etc.



Energy Capture

PV deployment involves cost/efficiency trade-offs

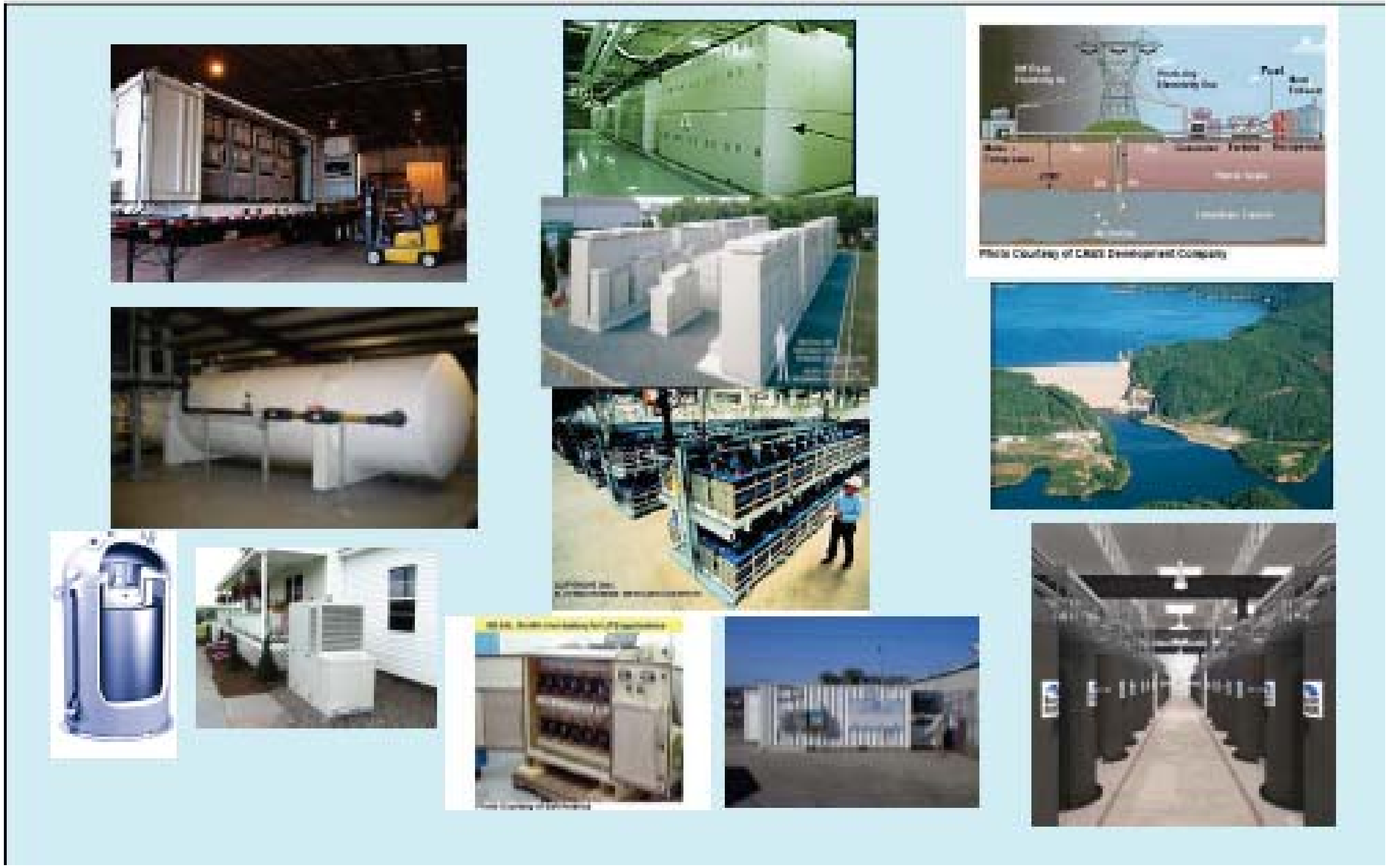
Wind speed/power output relationships are not fully deterministic.



Source: 3TIER

Enabling Technologies

Expect future solar and wind plants to include energy storage for purposes of economic optimization



End Product or Service

Like most renewable resources biomass can serve multiple end uses; the most profitable will drive innovation and industry growth. Non-conversion costs drive plant location and scale.

Category	Total Capacity
Electricity CHP Heat	4,650 MWe 9,050 MWt
Heat	11,700 MWt
Biochemical Biofuel	1.5 BGY gasoline equivalent
Thermochemical Biofuel	1.7 BGY diesel equivalent
Biomethane	106 BCF/y methane
Hydrogen (bio ' thermal)	2.5 Million tons/y

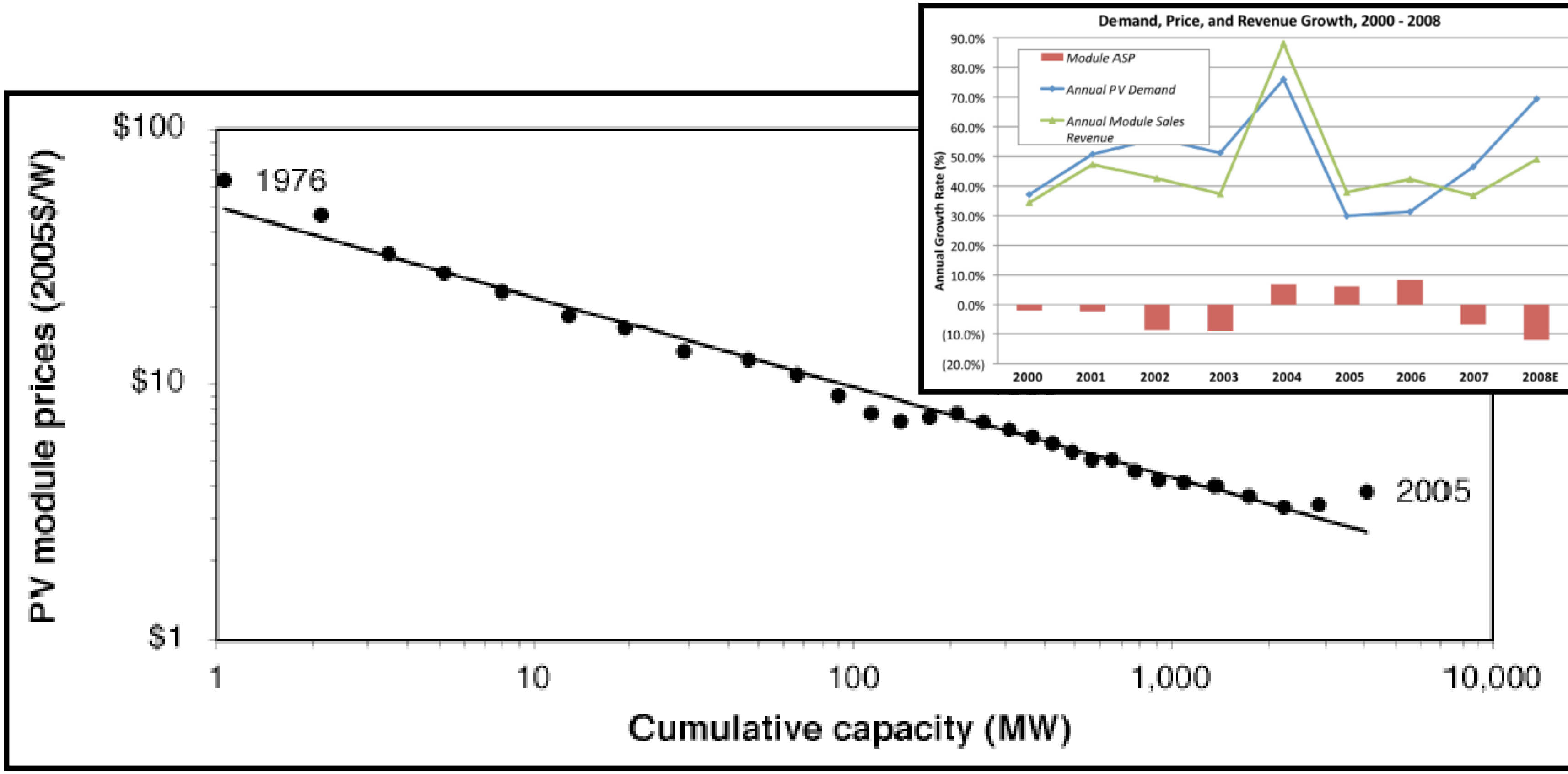
Bio-energy Value Chain

- PRODUCTION
- HARVESTING/COLLECTION
- HANDLING
- TRANSPORT
- STORAGE
- PRE-TREATMENT (MILLING..)
- FEEDING
- CONVERSION
- COLLECTION
- STORAGE
- DELIVERY

California Bio-Energy Potentials (Source: California Biomass Collaborative)

Manufacturing – Scale

Manufacturing scale can drive learning curves, as with PV.
Thus, market size and growth can be significant cost drivers.



Sources: http://www.iea.org/textbase/work/2007/learning/Nemet_PV.pdf, and Prometheus Institute

Manufacturing – Materials

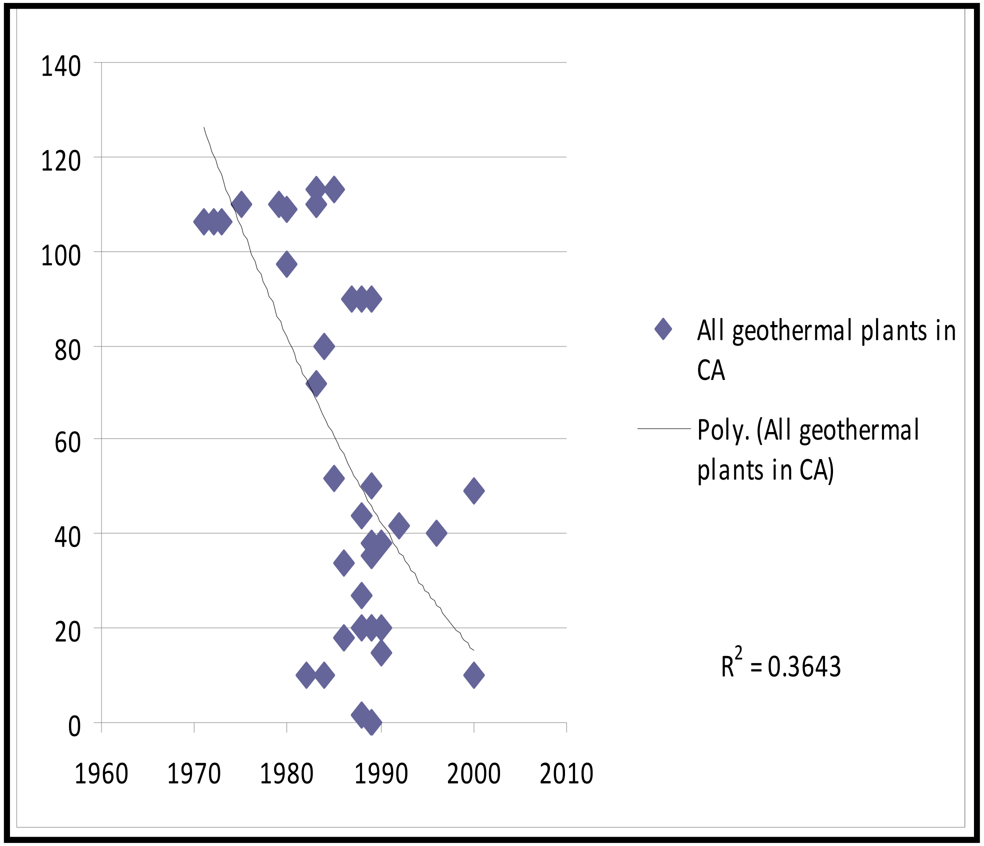
Renewable energy plants and components are materials intensive. Global supply and demand constraints may impact both short and long term costs.

Classification of PV Manufacturers for Cost Modeling					
Number	Technology	Supply chain concentration	Location	Distinguishing feature	Example companies
1	Multicrystalline Si	Polysilicon-to-module	Global	Sources own polysilicon meaning lower-than-average feedstock price	REC, SolarWorld
2	Multicrystalline Si	Module	Europe	High contracted polysilicon position	BP Solar
3	Multicrystalline Si	Module	Asia	Lower labor, utilities costs	Suntech Power, Sharp
4	Super Monocrystalline Si	Module	N/A	High efficiency	SunPower, Sanyo
5	CdTe	Feedstock-to-module	N/A	Technology	First Solar
6	CIGS	Feedstock-to-module	N/A	Technology	Nanosolar, Miasole
7	A Si	Feedstock-to-module	N/A	Technology	Moser Baer, Kaneka Silicon PV

Source: Prometheus Institute

Plant Scale

Costs and efficiencies of thermal power plants improve with scale, but resource delivery and project development costs may tip the balance toward smaller plants.



Source: California Geothermal Energy Collaborative

Plant Functionality

Configuring renewable energy plants to minimize overall electric system cost will be enabled by a range of technical integration solutions, e.g. thermal energy storage.

Equipment Modularity

Some emerging renewable energy technologies may require profitable entry and intermediate markets in order to gain commercial experience leading to cost eductions.

50kW Walnut Shell Gasifier

25kW Solar Dish w/Stirling Engine

Economic Context

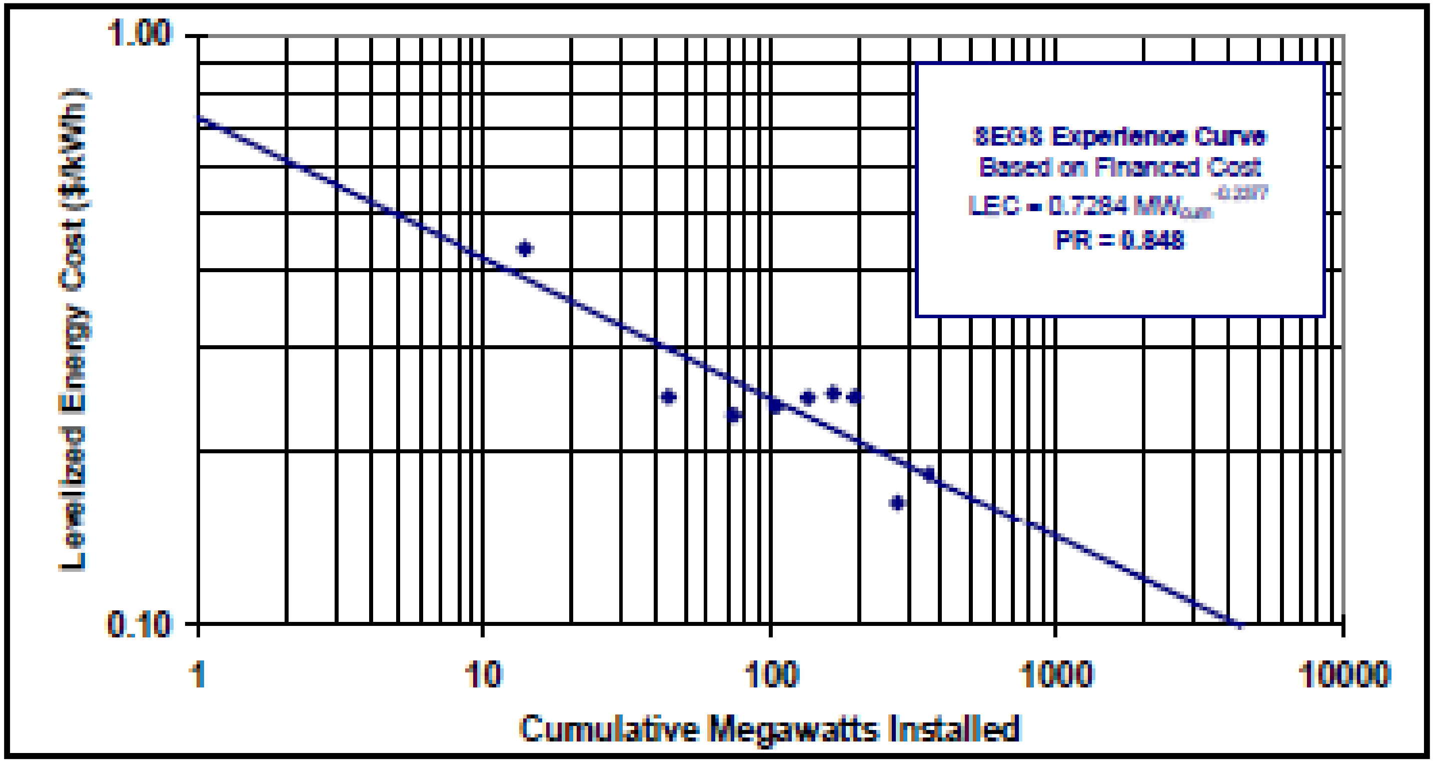
User finance

Project finance – wholesale avoided cost purchase

Installer finance – retail avoided cost purchase

Deployment Experience

A tale of death and taxes, solar thermal power deployment experience in California also illustrates a cost reduction strategy based on plant replication, incremental innovation and scale-up.



Issues Redux - 1

Issue: Cost estimation in the context of fast changing cost drivers and proliferating options

Response:

- Initiate in-depth future-oriented cost analysis
  - Focus on major contributors to least-cost future mix
  - Understand global market trends and dynamics
- Expect analytical contributions from California Renewable Energy Collaboratives
  - Commission-funded through PIER
  - Cost analysis included in 2 year work scope

Issues Redux - 2

Issue: Metrics and methods for evaluating variable resources and community- and building-scale options

Response: Integrated energy supply models

- Renewable energy supply contributions at all levels
- Natural gas as an enabler vs. alternative
- Whole system optimization capability

COG Project Data Development

- Study design:
  - Simplify by focusing on commercially established options
  - Assess potential for future technology shifts
  - Sanity check cost estimates using pricing data
  - Model evolutionary changes
  - Preliminary look beyond (i.e. below) utility scale

Summary

- Deployment to date:
  - Utility scale – substantial base plus project development
  - Community scale – pilot projects and regulatory barriers
  - Building scale – PV approaching energy significant phase
- RE resource and technology base – diversity and endless variation
- Consultant study is designed to both:
  - Support EAO IEPR efforts
  - Bridge to more comprehensive analysis of future costs

Supplemental charts

Relative to 2007 IEPR…

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- Hydro
  - Lower mitigation costs for existing hydro sites
  - Lower capacity factor for hydro
- Lower solar PV single axis instant costs
  - 25MW (2009) vs.
  - 1MW (2007)
- Ocean wave
  - 40MW plant commissioned in 2018 (2009) vs.
  - O.75MW commissioned in 2007 (2007)
- Wind
  - Class 5 on-shore and off-shore commissioned in 2009 and 2018 respectively (2009) vs.
  - Class 3 and 4 on-shore (2007)
- Other – higher IGCC capacity factors and higher nuclear instant costs

Reference to CPUC/RETI

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Differences from CPUC/E3

- Include costs for utility scale single axis PV
- Higher solar thermal instant costs
- Class 5 wind capacity factors vs. classes 3 and 4
- Spike in construction cost inflation not assumed
- Cost of transmission and voltage conversion to first local interconnection point
- “Firming costs” (CTs needed to reach 90% availability on peak) not assumed for small hydro and wind

Differences from RETI/B&V

- General consistency except single axis PV costs are lower

Facts of RE Project Finance

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1. RE projects are capital intensive.
2. Capital is allocated according to risk and return.
3. Perceptions and allocations of risk determine the cost of project capital.

Risks	Opportunities
Project capital cost	Lenders
Project operating cost	Owners
Project revenue	Builders
	Manufacturers