



Systems Driven Methodology & Tools

Experiences from the DOE CSP program

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Methodology

- 1) Understand current and future markets
- 2) Estimate the potential impact of the technology/market
- 3) Establish the current technology ‘baseline’
- 4) Evaluate avenues for improvement
- 5) Decide how to allocate limited resources (\$)
- 6) Repeat when conditions change
 - Markets or knowledge of markets
 - Knowledge of technology
 - Program resources change



1) Understand the Market(s)

- **Identify important metrics (e.g. Levelized Energy Cost)**
 - LEC not the one perfect metric, but probably the best
 - Incorporates initial cost, performance, O&M (incl. reliability), financial terms
- **Value also important**
 - Cost – Value (e.g. 5 c/kWh over competition)
 - Cost/Value (e.g. 25% over competition)
- **Other requirements to deploy the technology?**
 - Aesthetics, size, reliability, complexity, shipping, water use
- **What is the competition? Is it penetrating the market?**
 - Solar hot water, remote diesel



Market Analysis/Prediction Tools

- “Independent” analyses may have more credibility
 - Energy Information Agency (EIA)
 - Platts, other industrial sources
- Determine market ‘value’ targets
 - Utility scale: peak vs. off-peak value varies
 - Remote: market size = fcn(cost) ... demand elasticity
 - Example: CSP Trough/Tower goal = 4-6 c/kWh
- Utility markets better defined than distributed, remote, residential markets



Calculating LEC

- **Constant vs. current dollar analysis**
- **‘Economic-level’ calculations**

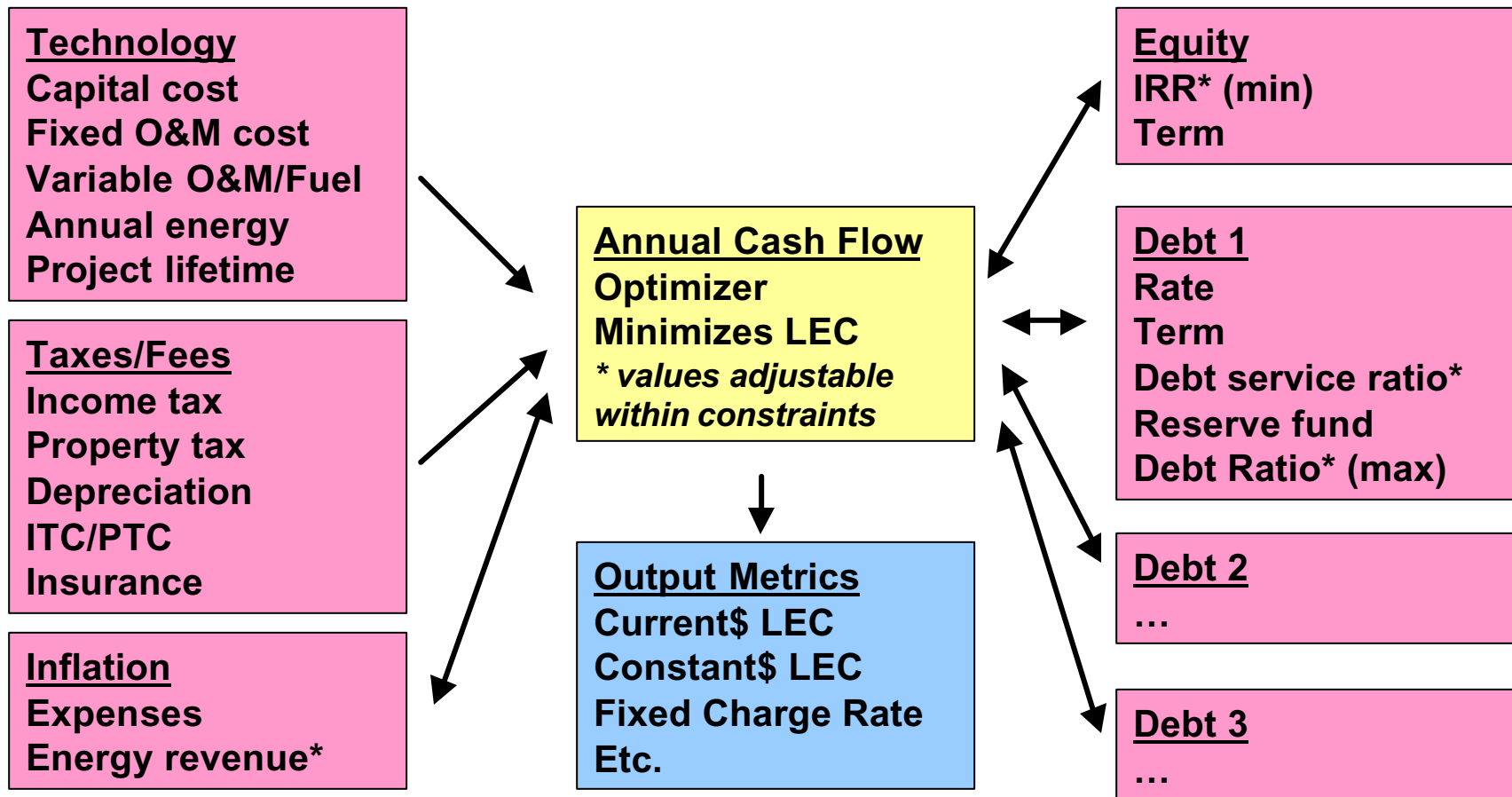
$$\text{LEC} = \frac{\text{CC}(\$) \times \text{FCR} + \text{O \& M}_{\text{fixed}}(\$)}{\text{Annual Energy (kWh)}} + \text{O \& M}_{\text{variable/fuel}} (\$/\text{kWh})$$

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- **‘Financial-level’ calculations**
 - Cash flow analyses done for real projects
 - Can provide additional insights and accuracy
 - Incentive analysis for 1,000 MW initiative
 - Back out effective FCR from cash flow analyses
- **Financial assumptions**
 - Consistency important in evaluations
 - Typical values may vary with market segment



Cash Flow Model Schematic





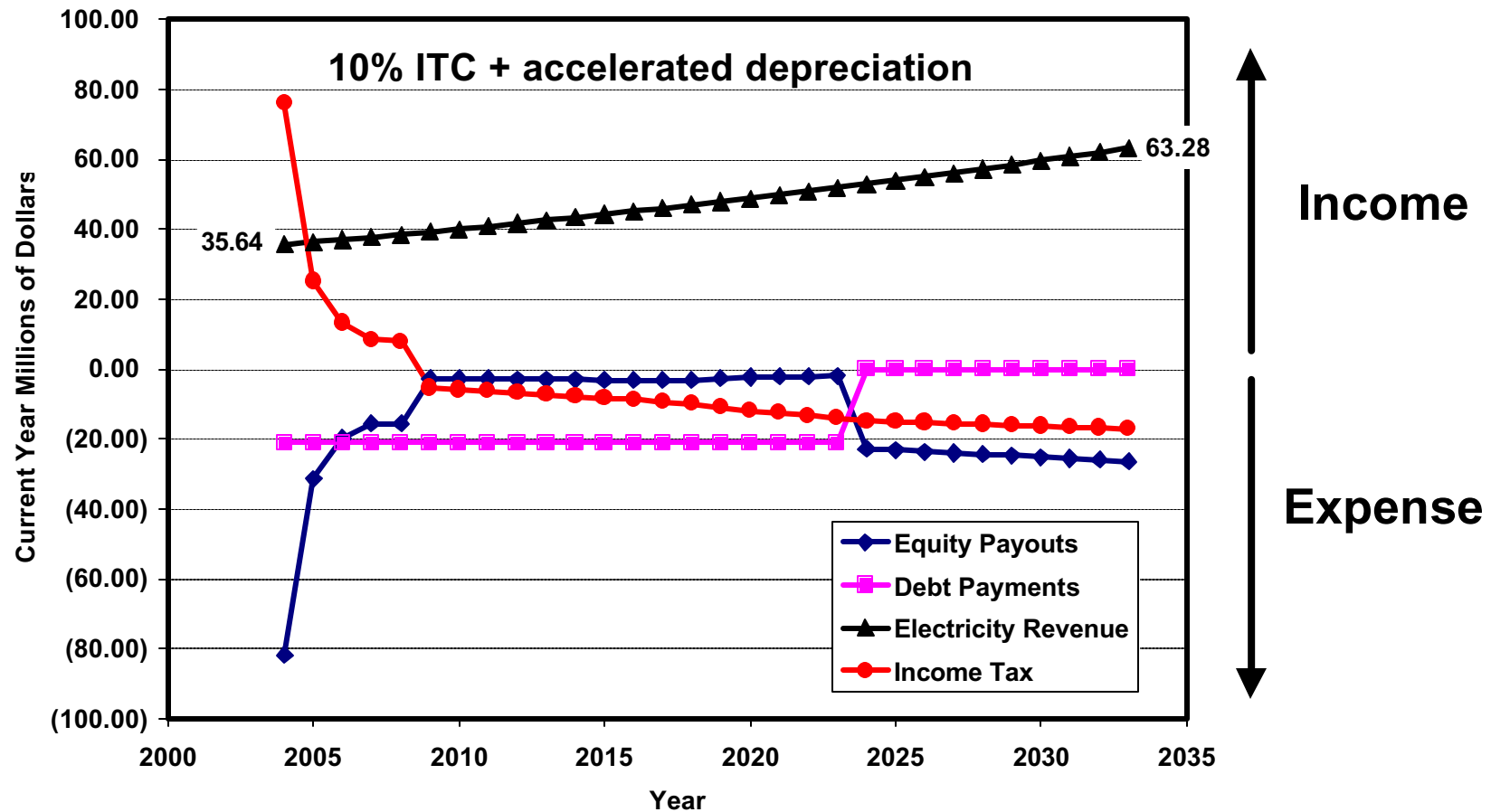
Example: Cash Flow Model Results

- CSP Power Tower Mid-Term Solar 100 plant
- CC = \$311M, O&M = \$0.005/kWh, Ann. Eff. = 16.5%
- Existing tax incentives: 10% ITC, accelerated depreciation

Selected Inputs	IPP Hi	IPP low	Corp Hi	Corp low
Debt Rate, Term	8%, 10-yr	8%, 10-yr	7%, 20-yr	7%, 20-yr
Minimum Equity IRR	18%	12%	18%	12%
Selected Outputs				
LEC (Current\$/kWh)	0.088	0.065	0.063	0.049
Nominal FCR	16.1%	11.7%	11.1%	8.7%
LEC (2002\$/kWh)	0.070	0.049	0.048	0.037
Real FCR	12.5%	8.7%	8.4%	6.3%
Optimal Debt Ratio	52%	44%	63%	61%



Example: Solar 100 Corp Hi





2) Estimate the Potential Impact

- **How big is the market?**
- **Maximum market share?**
- **What is the potential benefit to society?**
 - Environment or Security
- **Example: CSP benefits story**
 - Vast, renewable resource exceeds global demand
 - Dispatchability shaves peak periods, higher value
 - High CF permits high portfolio penetration
 - Able to make significant impact on global warming
 - Thermo-chemical options impact energy security



3) Establish Technology ‘Baseline’

- **Develop and validate models of the system**
 - Performance
 - Cost
 - Component level & system level
 - Be realistic about the current status of the technology
 - E.g. SEGS experience tapped w/ O&M cost reduction project
 - Other metrics
 - Dish reliability database
 - Some metrics hard to quantify (e.g. aesthetics, complexity)



Technology models

- **One model probably impractical for handling even a single technology**
 - **Subsystem Physical models**
 - Receiver thermal and mechanical behavior
 - Power cycle thermodynamics steady state and transient
 - Optical performance/optimization
 - **Annual system performance**
 - Uses physical model result input (e.g efficiency)
 - Off-design operation: startup, shutdown, part-load, offline
 - Impact of variable resources, siting
 - **Installed Cost Models**
 - **Financial models**
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Cost Models

- **Cost sometimes proprietary. Price often easier to get.**
 - Costs are location and time dependent (+/- 20%)
 - Avoid attributing technology trends to this variability
 - Identify commodity and custom parts
 - Get vendor quotes if possible. Benchmark against other products.
 - Use care in projecting impact of volume production (e.g. learning curves)
 - **Other costs**
 - Project development costs, insurance, etc.
 - Infrastructure (e.g. T&D)
 - Contingencies
 - Shipping
 - Profit
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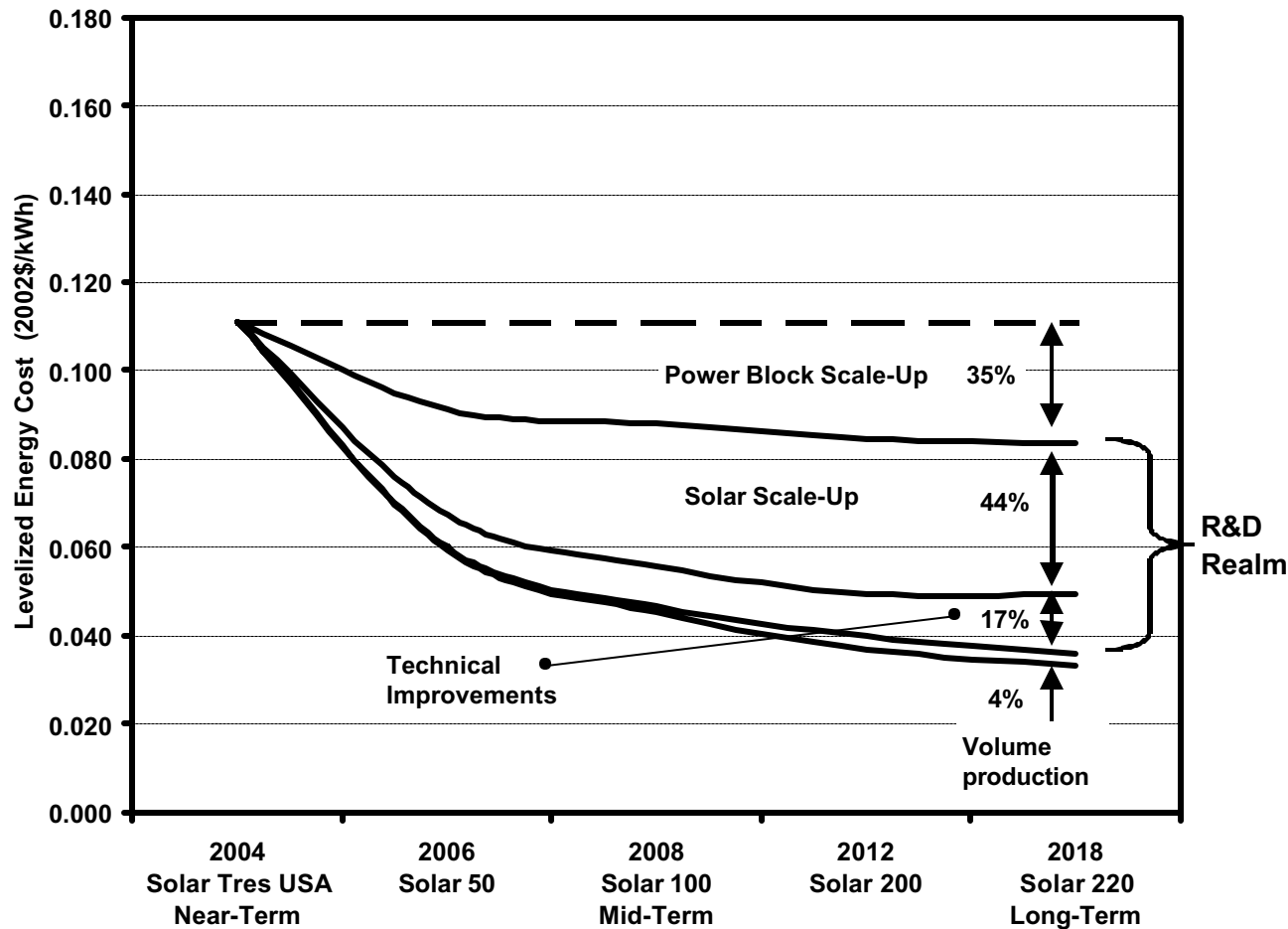


4) Evaluate Avenues for Improvement

- **Consider all aspects (capital cost, O&M, performance, financial)**
 - E.g. tax equity
 - Incremental and substantial changes
- **Parametric studies on avenues for improvement**
 - Isolate impact of each change on baseline system metrics
 - Caution: impacts (%LEC reduction) on baseline may not be additive
- **Technology roadmap showing system evolution including effects of multiple changes**



Example: Tower LEC by Category



- Learned new things
- Scale-up largest effect
- Huge heliostat production volume not necessary



5) Decide how to allocate limited resources (\$)

- **Analyze cost/benefit/risk tradeoffs**
 - Estimate risk, use judgment in decision making
 - Statistical tools helpful, can't replace judgment
 - **'Low-hanging fruit' + long-term goals**
 - **High risk, high payoff sometimes appropriate**
 - **Consider roles of industry, labs, etc.**
 - **Technology demonstration (risk reduction) important in the commercialization process**
 - **Develop Technology roadmaps + RD&D plans**
 - Set milestones
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Summary

- **Poor models or poor input data = poor results**
 - **Consistency of assumptions or optimism**
 - Labor rates (e.g. \$30/hr for power plant O&M, \$60/hr for residential service call)
 - Materials costs (commodity vs. custom parts)
 - Financial Terms
 - **Addressing uncertainty**
 - Scenario analysis (low, medium, high)
 - Quantify uncertainty of every input (not likely)
 - Acknowledge differences in prediction accuracy
 - Current vs. distant future
 - Learning curves, validated scaling factors, vendor quotes
 - R&D risk fundamental or applied
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