Levelized Cost of Energy -- Making Economic Sense of Energy Options

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Outline

- Opening Comments
- *Levelized Cost of Energy 101*: Dr. Howard Axelrod, Energy Strategies, Inc.
- *Advanced Energy and Environmental Models for Electric Genera*tion: Professor Daniel Shawhan, Rensselaer Polytechnic Institute
- Q&A

Levelized Cost of Energy - 101

- What are we trying to evaluate?
- Why do the characteristics of electric energy sources change the way we value them?
- What is Engineering Economics and how does LCOE fit in?
- Defining LCOE including advantages and disadvantages.
- Examples of LCOE studies.

What are we trying to evaluate?

- Alternative sources of electricity including:
  1. Conventional sources of generation – coal, nuclear, gas
  2. Renewable Resources – wind, solar, biomass
  3. Energy Conservation and Demand Management
- An economic ranking system that considers:
  1. Initial and future capital costs
  2. Annual operation and maintenance costs
  3. Environmental Impacts

Why do the characteristics of electric energy sources change the way we value them?

- The size of electric generation is measured by its capacity (megawatts) and its output (megawatt-hours) – base load generation operate 24 hours per day whereas peakers operate only a few hours per day.
- Intermittent generation (solar or wind) only operate under limited conditions and have little “demand” value. Conventional generation can operate within a predetermined schedule.
- Some generation can last for 50 or more years; while other forms less than 10 years
- Similarly, some forms of generation are capital intensive; while others have high annual operating and/or maintenance expenses
- Finally, some generation have a direct environmental impact; while others the impact is exogenous.

A comparative economic analysis needs to consider all of these differences.

What is Engineering Economics and How does LCOE fit in?

- ***Engineering economics****, previously known as* ***engineering economy****, is a subset of economics for application to engineering projects. Engineers seek solutions to problems, and the economic viability of each potential solution is normally considered along with the technical aspects.* (Wikipedia)
- For engineering students seeking a PE license, engineering economics is a pre-requisite and can represent 20% of the PE exam.
- Generally, LCOE is the unit cost of energy after considering the time value of money over the life of the facility.
- There are several formulas for LCOE based on application.

A common form of LCOE is the Unit Cost of Energy adjusted for the time value of money. However, there are a number of interpretations of LCOE that may produce different results.

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A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies

Walter Short, Daniel J. Packey, and Thomas Holt

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$$\sum_{n=1}^{N} \frac{Q_n \times LCOE}{(1+d)^n} = TLCC, \text{ or} \tag{4-6}$$

$$LCOE^{22} = TLCC \div \{\sum_{n=1}^{N} [Q_n \div (1+d)^n]\}$$

Where:

LCOE	=	levelized cost of energy
TLCC	=	total life-cycle cost
Q_n	=	energy output or saved in year n
d	=	discount rate
N	=	analysis period.

LCOE's Strengths and Weaknesses

Strengths

- Provides a common basis for comparing generation of varying operating lives.
- Reflects time value of money including real cost of money (including risk) and inflation.
- Easily understood with a common definition of economic value

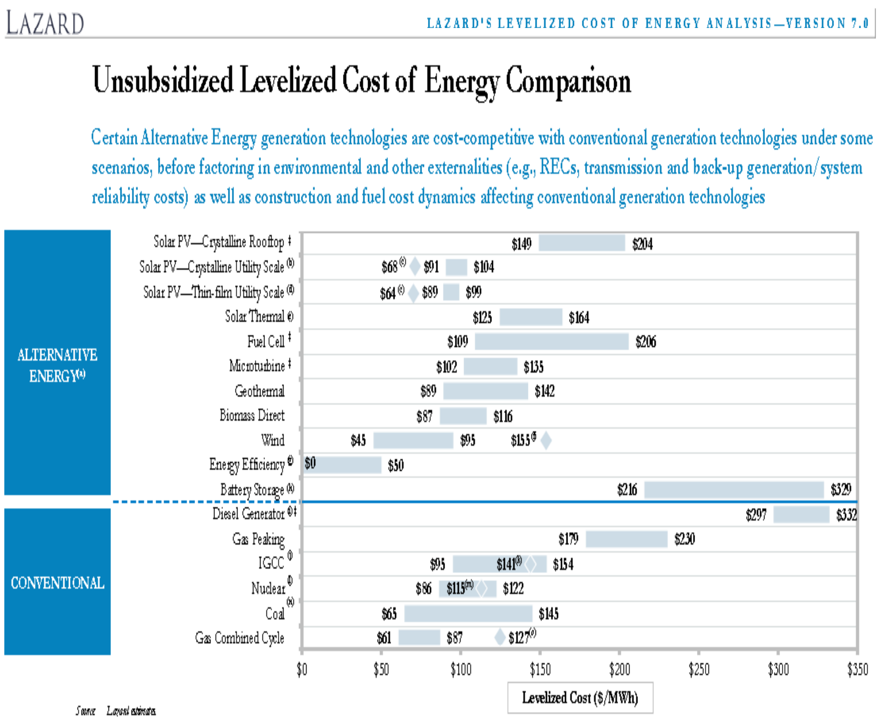
Weaknesses

- Fails to value scheduled versus intermittent (non-dispatchable) qualities
- Fails to value short versus long lived assets
- Fails to value base load versus peaking generation
- Does not consider annual cash flow

Why LCOE, or, in fact, Engineering Economics provides only a partial picture of alternative valuations

- Engineering Economic studies do not adequately evaluate such other important determinants as:
  - Impact on earnings and cash flow
  - Debt financing and impact on bond ratings
  - Electric rate impacts
  - Payback period

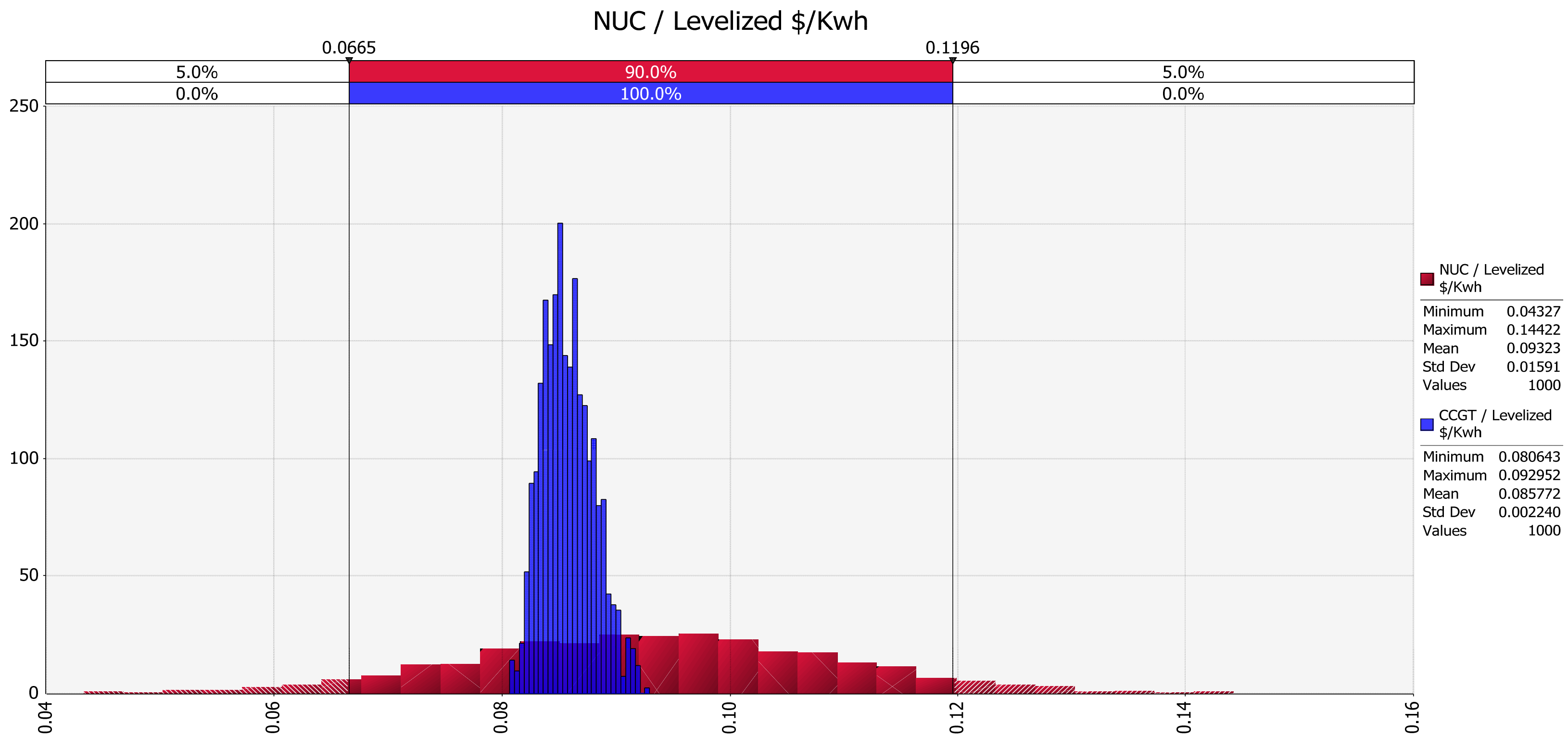
Examples of recent LCOE studies



U.S. Average Levelized Costs (2011 $/MWh) for Plants Entering Service in 2018				
Plant Type	Capacity Factor (%)	Range (sorted by average)		
		Minimum	Average	Maximum
Natural Gas - Conventional Combined Cycle	87	62.5	67.1	78.2
Wind - Onshore	34	73.5	86.6	99.8
Geothermal	92	81.4	89.6	100.3
Hydro	52	58.4	90.3	149.2
Natural Gas - Advanced CC with CCS	87	87.4	93.4	107.5
Advanced Nuclear	90	104.4	108.4	115.3
Biomass	83	98.0	111.0	130.8
Advanced Coal	85	112.6	123.0	137.9
Advanced Coal with CCS	85	123.9	135.5	152.7
Solar PV	25	112.5	144.3	224.4
Wind - Offshore	37	183.0	221.5	294.7
Solar Thermal	20	190.2	261.5	417.6

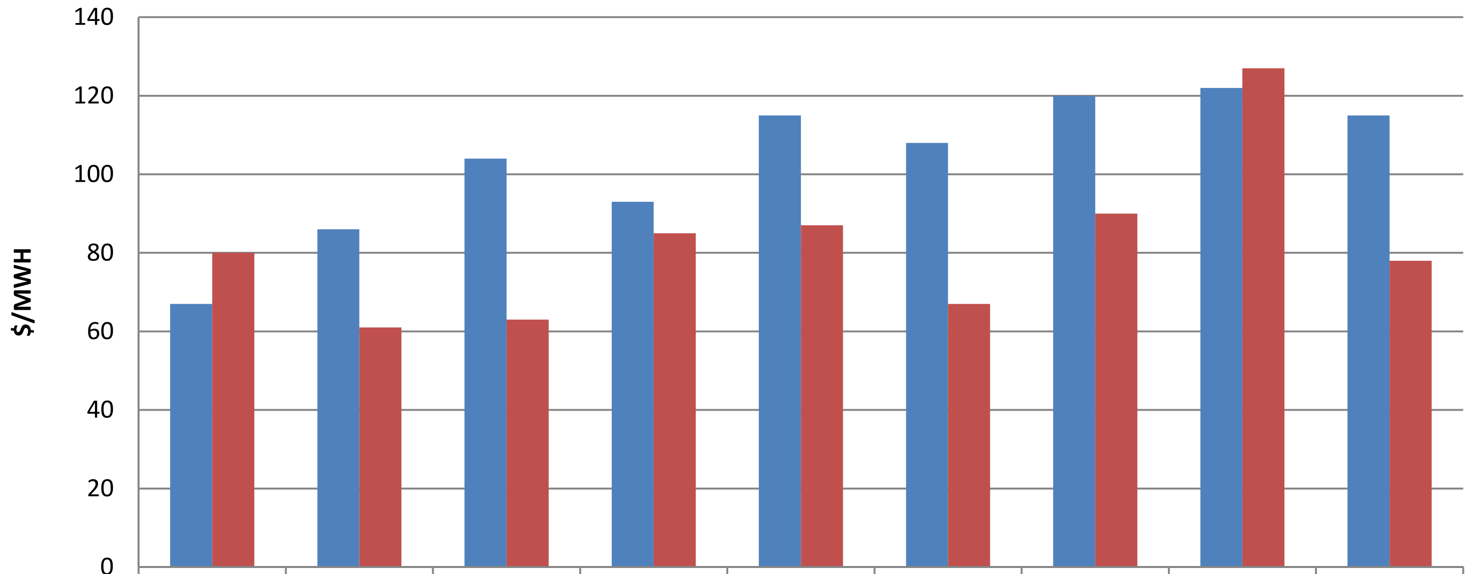
Source: Energy Information Administration, Annual Energy Outlook 2013, December 2012

The ESI LCOE Forecast uses @Risk Monte Carlo model to estimate 90%confidence band



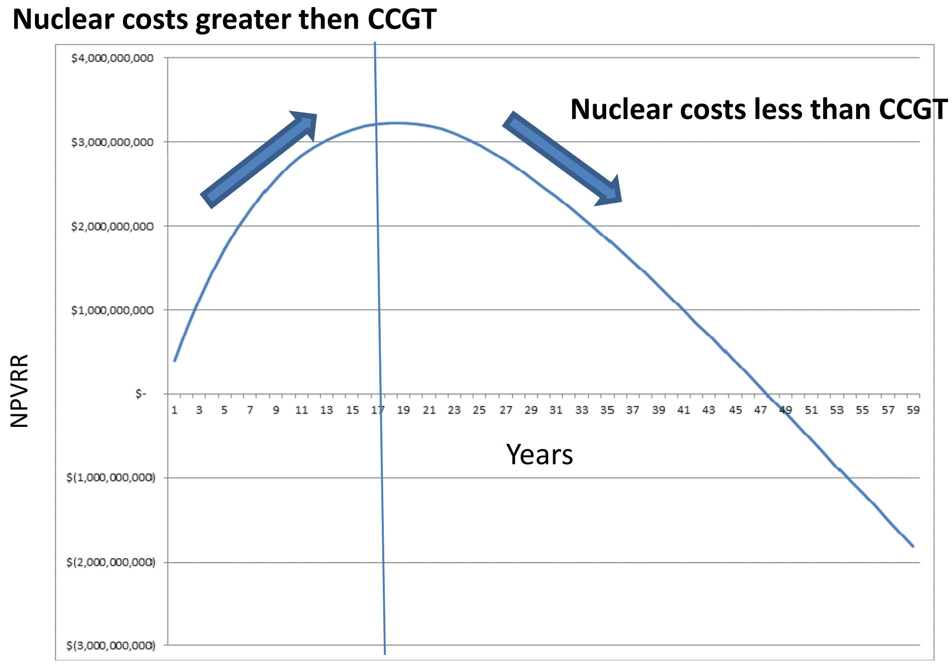
Comparison of 3 LCOE Forecasts

Levelized Cost of Nuclear vs CCGT



	ESI Min	LAZ Min	EIA Min	ESI Mean	Laz Mean	EIA Mean	ESI Max	Laz Max	EIA Max
Nuclear	67	86	104	93	115	108	120	122	115
CCGT	80	61	63	85	87	67	90	127	78

Both NPV & LCOE fail to measure annual costs, rate impacts or financial exposure



- In this illustrative scenario, the NPV of total revenue requirements favors nuclear power by ~ $2 billion
- However, on an annual basis, the NPV accumulates to over $3 billion more for nuclear during the first 17 years, declining to $0 in the 48th year of operation.
- While NPV is lower than alternative, rate impacts and cost of financing makes the alternative a viable choice.

LCOE is a useful screening tool to prioritized candidate investments – *but it is just the 1st step*.

1. Screening Level Assessment
   – Categorize projects by operational mode
   – Calculate LCOE & NPV
2. Detailed Cost & Operational Analysis
3. Comprehensive Annual Revenue Requirement and Financial Analysis
   – Financial impacts
   – Rate requirements

Closing Comments

- Because such renewable resources as wind and solar are typically non-dispatchable, economic comparisons with conventional generation can be misleading without further analysis.
- However, when paired together, e.g., solar and CCGT, the combined benefits of low operational costs and dispatchability may be feasible as long as the total unit cost of solar or wind is equal or less than the avoided cost of the CCGT.

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Howard J. Axelrod has more than 40 years of experience in management consulting, strategic planning and marketing for the electric and gas industry. He is founder of Energy Strategies, Inc. and serves as the firm's President and Chief Executive Officer. He is also the acting Chief Risk Officer for a New England based municipal wholesale electric company. With proficiencies in economics, marketing, and power systems planning, he provides a multi-disciplinary approach to resolving complex business and regulatory issues. He has performed numerous studies and led in the development of strategies addressing such issues as competitive restructuring, strategic business and market planning, organizational development, and business risk analysis.

Howard was awarded his Doctorate in Managerial Economics from Rensselaer Polytechnic Institute, an MBA from SUNY Albany and MSEE and BSEE degrees in Power Systems from Northeastern University. He also completed General Electric's 3-year Application Engineering Training Program. Howard has over 25 publication and presentation citations and has testified in over 40 regulatory proceedings.

His professional associations include Life Membership in the Institute of Electrical and Electronic Engineering, Senior Membership in the Power and Energy Society, Member of the Profession Risk Managers Association and Professional Engineer (retired license in New York)