BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH



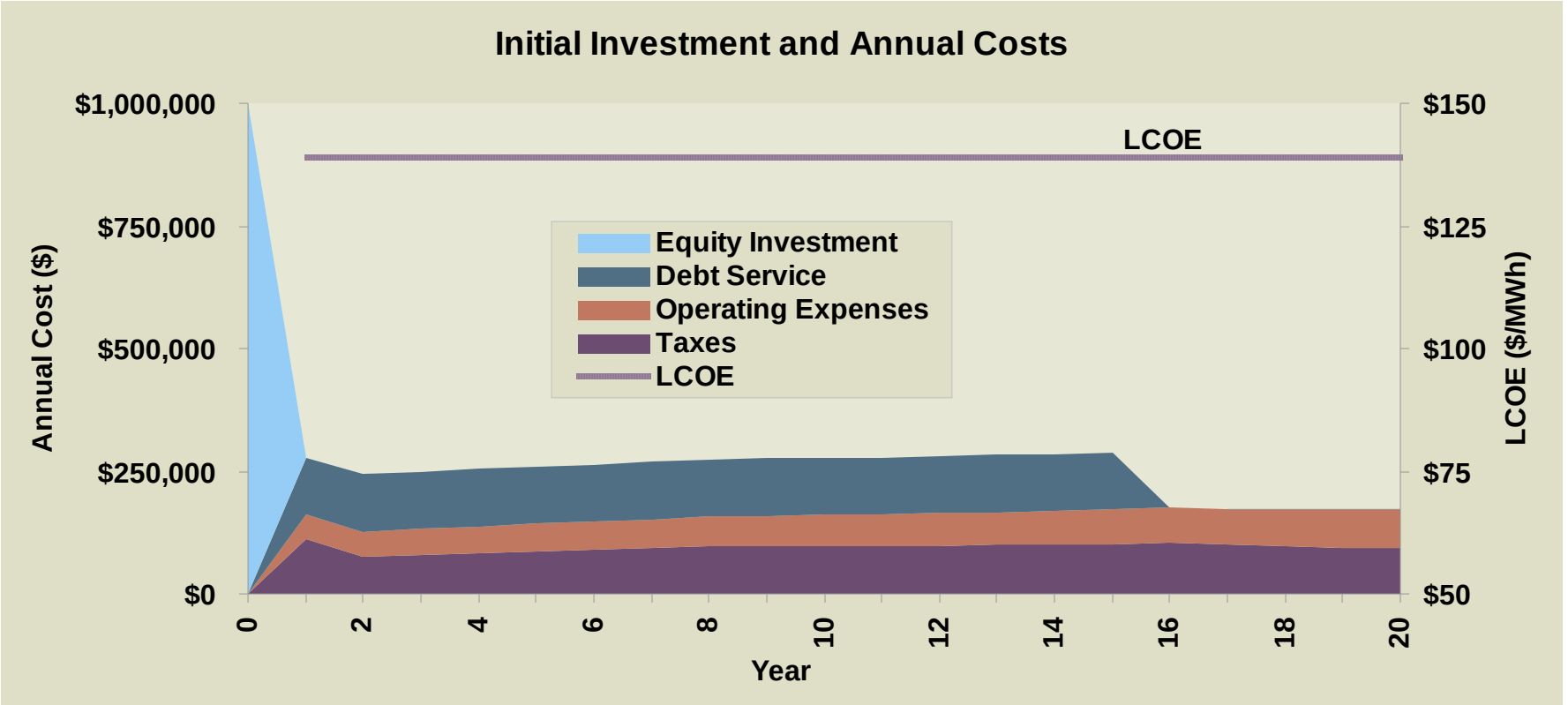


1: Levelized Cost of Energy Calculation

Methodology and Sensitivity

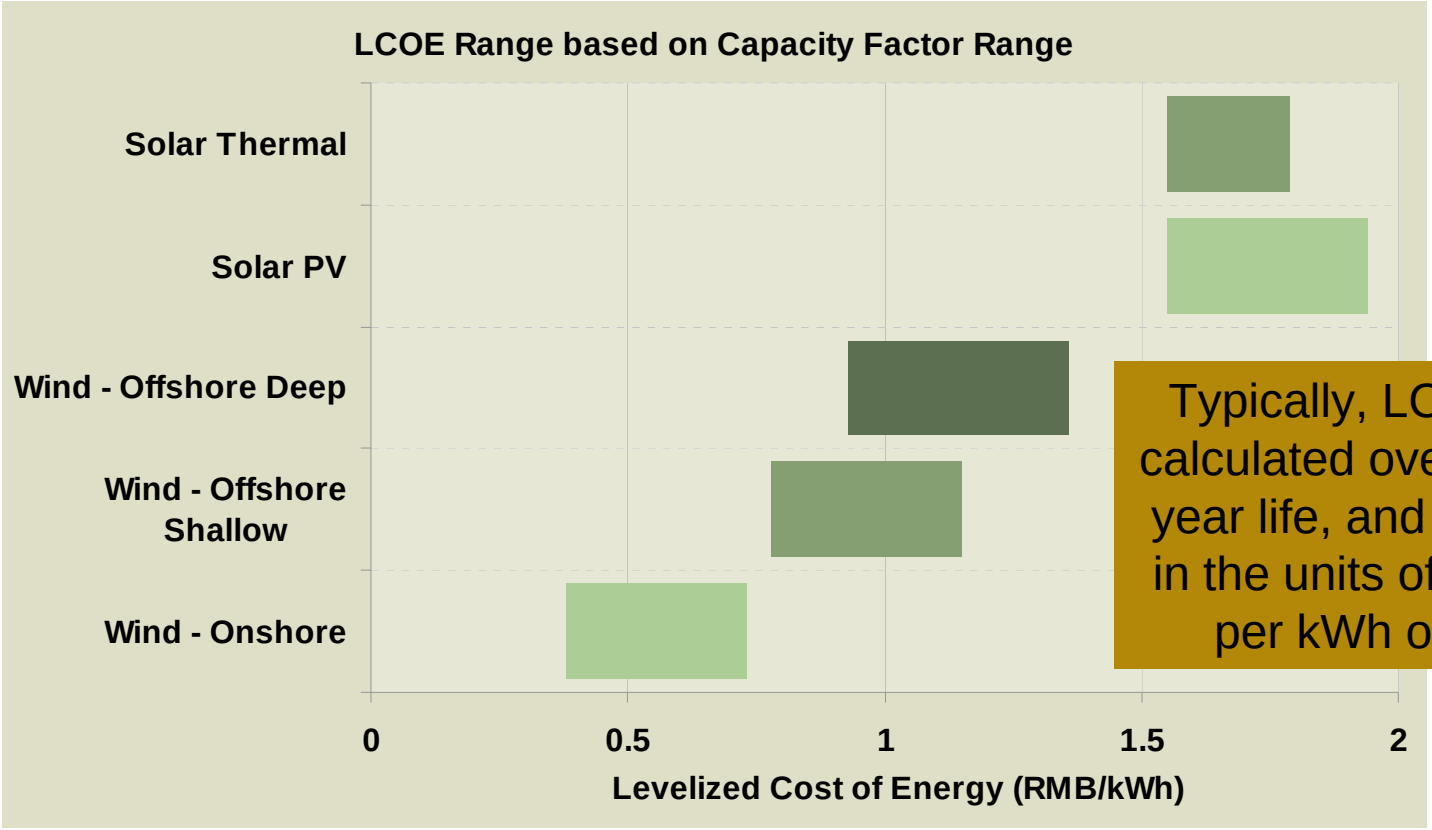
What is LCOE?

- **Levelized Cost of Energy (LCOE)** is the **constant unit cost** (per kWh or MWh) of a payment stream that has the same **present value** as the total cost of building and operating a generating plant over its life.



Why Use LCOE?

- Very useful in comparing technologies with different operating characteristics



Typically, LCOEs are calculated over 20 to 40 year life, and are given in the units of currency per kWh or MWh

Different Ways to Calculate LCOE.

Simplified LCOE Approach

1. Using a discount rate *i*, the capital recovery factor (CRF) is:

$$CRF = \frac{i(1+i)^n}{[(1+i)^n]-1}$$

2. The sLCOE is the minimum price at which energy must be sold for an energy project to break even (or have present value of zero)

$$sLCOE = \frac{[(\text{capital cost} * CRF) + \text{fixed O\&M cost}]}{(8.76 * \text{capacity factor})} + (\text{variable O\&M cost} * \text{output})$$

- **Discount rate**
  - Used to convert future costs to present value.
  - Typically based on market interest rates or weighted cost of capital (WACC), with or without adjustments for risk and uncertainty.
  - Can vary depending on the entity.
  - Can be Real or Nominal

Different Ways to Calculate LCOE.

Cost of Generation Calculator

All inputs are in blue.

Technology Assumptions	
Project Capacity (MW)	1
Capital Cost ($/kW)	$2,000
Fixed O&M ($/kW)	$50
Fixed O&M Escalation	2.5%
Variable O&M ($/MWh)	$0
Variable O&M Escalation	2.5%
Fuel Cost ($/MBtu)	$0
Fuel Cost Escalation	2.5%
Heat Rate (Btu/kWh)	0
Capacity Factor	35%
Misc Revenue ($/MWh)	$0
Misc Escalation	2.5%
Degradation	1%

Financial/Economic Asumptions	
Debt Percentage	50%
Debt Rate	8.00%
Debt Term (years)	15
Economic Life (years)	25
Percent 5-year MACRS	0%
Percent 7-year MACRS	0%
Percent 15-year MACRS	0%
Percent 20-year MACRS	100%
Energy Price Escalation	0.0%
Tax Rate	50%
Cost of Equity	14.00%
Discount Rate	9.000%

Year	0	1	2	3	4	5
Annual Generation (MWh)		3,066	3,035	3,005	2,975	2,945
LCOE		$139.35	$139.35	$139.35	$139.35	$139.35
Misc Revenue		$0.00	$0.00	$0.00	$0.00	$0.00
Total Operating Revenue		**$427,249**	**$422,976**	**$418,746**	**$414,559**	**$410,413**
Fixed O&M		$50,000	$51,250	$52,531	$53,845	$55,191
Variable O&M		$0	$0	$0	$0	$0
Fuel Cost		$0	$0	$0	$0	$0
Operating Expenses		**$50,000**	**$51,250**	**$52,531**	**$53,845**	**$55,191**
Interest Payment		$80,000	$77,054	$73,872	$70,435	$66,723
Principal Payment		$36,830	$39,776	$42,958	$46,395	$50,106
Debt Service		**$116,830**	**$116,830**	**$116,830**	**$116,830**	**$116,830**
Tax Depreciation - 5		$0	$0	$0	$0	$0
Tax Depreciation - 7		$0	$0	$0	$0	$0
Tax Depreciation - 15		$0	$0	$0	$0	$0
Tax Depreciation - 20		$75,000	$144,380	$133,540	$123,540	$114,260
Taxable Income		$222,249	$150,292	$158,804	$166,739	$174,239
PTC		$0	$0	$0	$0	$0
Taxes		**$111,124**	**$75,146**	**$79,402**	**$83,370**	**$87,120**
Total	***(1,000,000)***	***149,295***	***179,750***	***169,984***	***160,515***	***151,273***

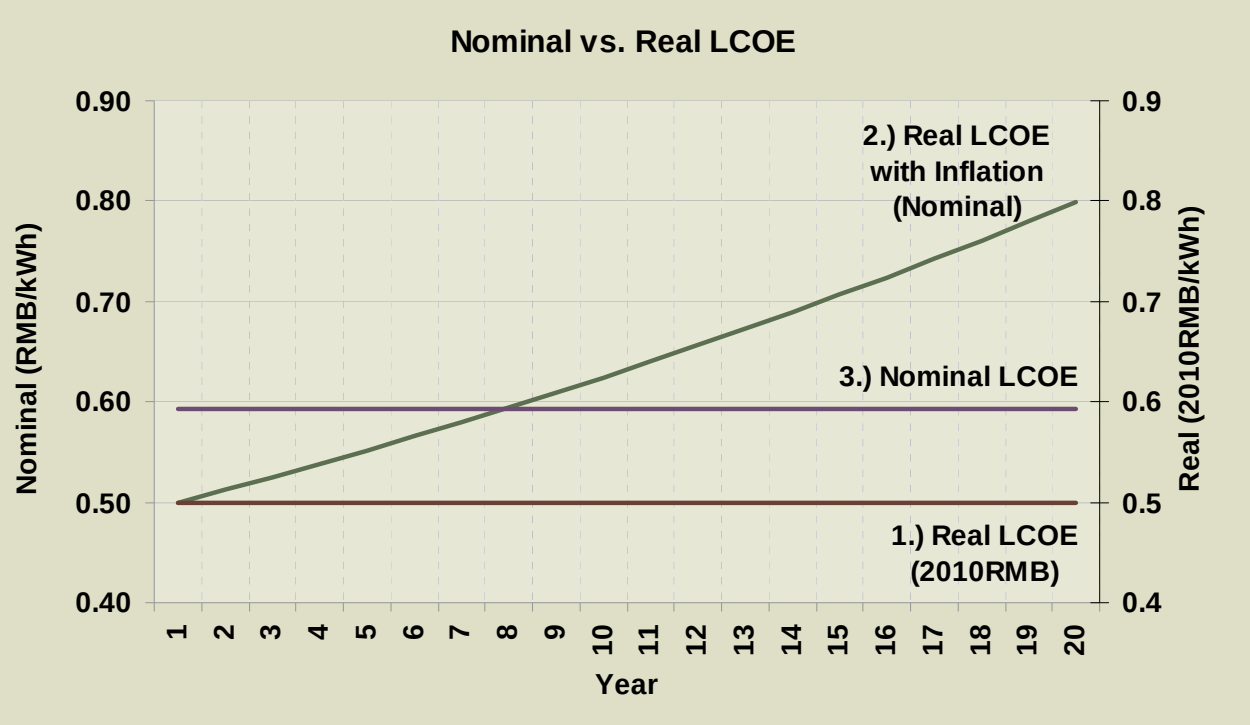
SAMPLE FINANCIAL MODEL

Financial Model Approach

- Financial model that solves for the required revenue (LCOE) to achieve a certain internal rate of return (IRR).
- Captures impacts of tax incentives and depreciation.
- Captures more complex financing assumptions and revenue requirements for an IPP

Real or Nominal LCOE?

1. **Real LCOE** (2010 RMB/kWh) – Constant stream of values denoted in today's currency (Real)
2. **Real LCOE (with Inflation)** (RMB/kWh)– Nominal path that maintains Real value constant (Nominal)
3. **Nominal LCOE** (RMB/kWh) – Constant stream of values in nominal currency. (Nominal)



Inflation = 2.5%

Discount Rate = 10%

Real or Nominal LCOE?

- **Real LCOE**
  - Removes effects of inflation associated with O&M and fuel costs
  - Uses Real Discount Rate
  - Analogous to the Year 1 price of a PPA/FIT that increases with inflation each year.
  - Preferred by government/policy makers
- **Nominal LCOE**
  - Incorporates assumptions regarding inflation
  - Uses Nominal Discount Rate
  - Analogous to a PPA/FIT price that is the constant each year or flat across economic life of project.
  - Preferred by developers/project owners

***Example:* Real LCOE = 0.50 RMB/kWh and Nominal LCOE = 0.59 RMB/kWh**

With 2.5% inflation, Nominal LCOE is 18% higher than Real LCOE

Either LCOE is acceptable, but must be clearly communicated.

General Inputs to LCOE Calculation

- Determine representative size of projects and locations to estimate remaining project-related inputs
  - For example, 10 MW wind farm vs. 200 MW wind farm

- Establish boundaries of system
  - Capital, O&M, fuel cost
  - Performance/resource characteristics
  - Cost of capital (debt/equity) and discount rate
  - Taxes, depreciation and tax incentives (if applicable)
  - Inflation (optional)
  - Transmission/integration costs (optional)
  - Externality costs (optional)

Making Good Assumptions

- Use current data (preferably within the past year)
- Take the median of data sources
- Apply method of developing assumptions consistently across technologies
- Survey market participants
- Reflect tax conditions and incentives in the country
- Discuss and agree upon assumptions through stakeholder meetings

Sample Base Case Assumptions and LCOE

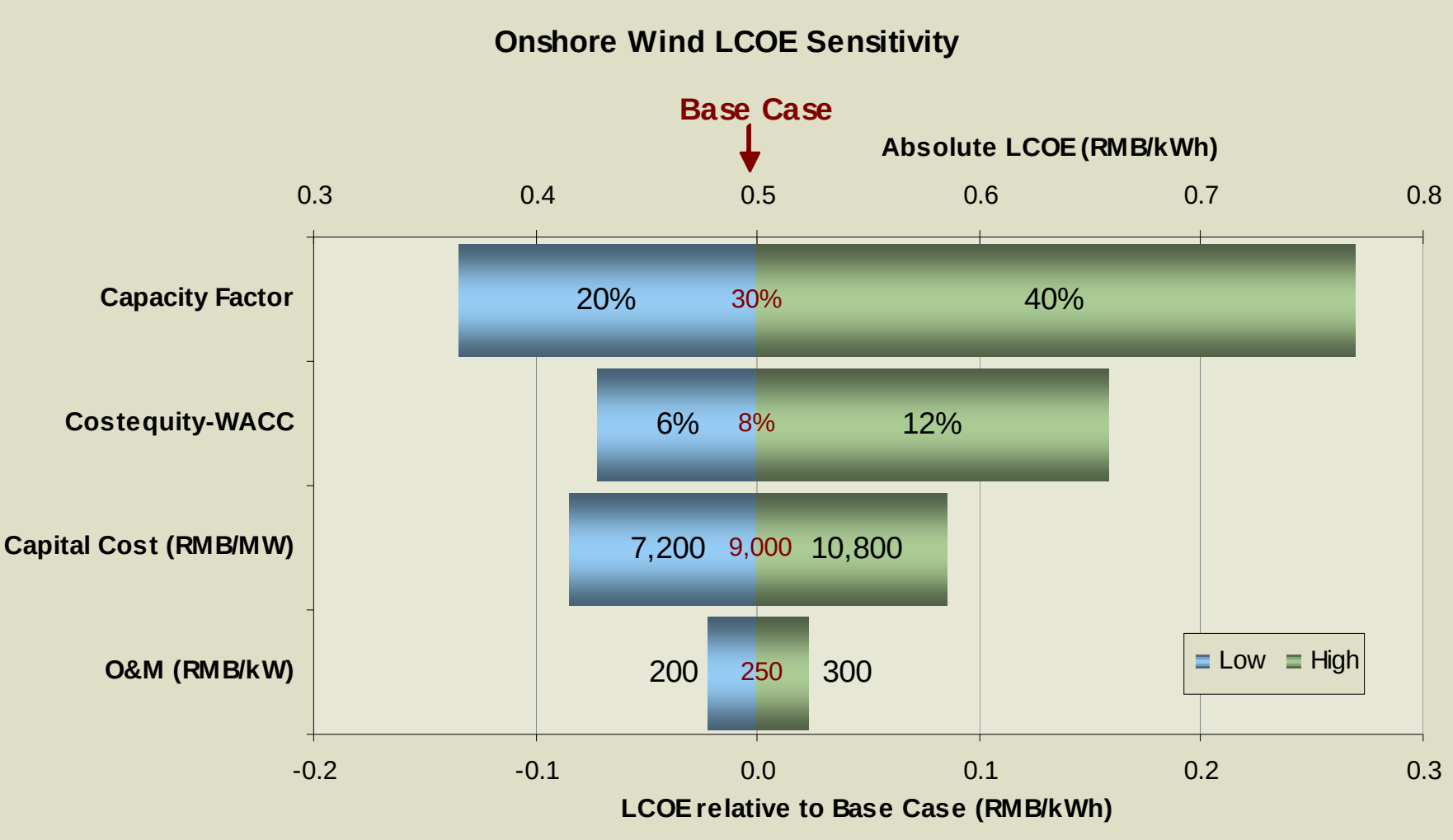
	Capital Cost (RMB/kW)	O&M (RMB/kW-yr)	Capacity Factor	LCOE (RMB/kWh)
Onshore Wind	9,000	250	40%	**0.54**
Solar PV	20,000	200	15%	**1.72**
Solar CSP	30,000	300	28%	**1.66**

Economic Life	20 years		Discount Rate	10%
Tax Life for Depreciation	20 years		Tax Rate	30%
O&M Escalation	2.5%		WACC	8%

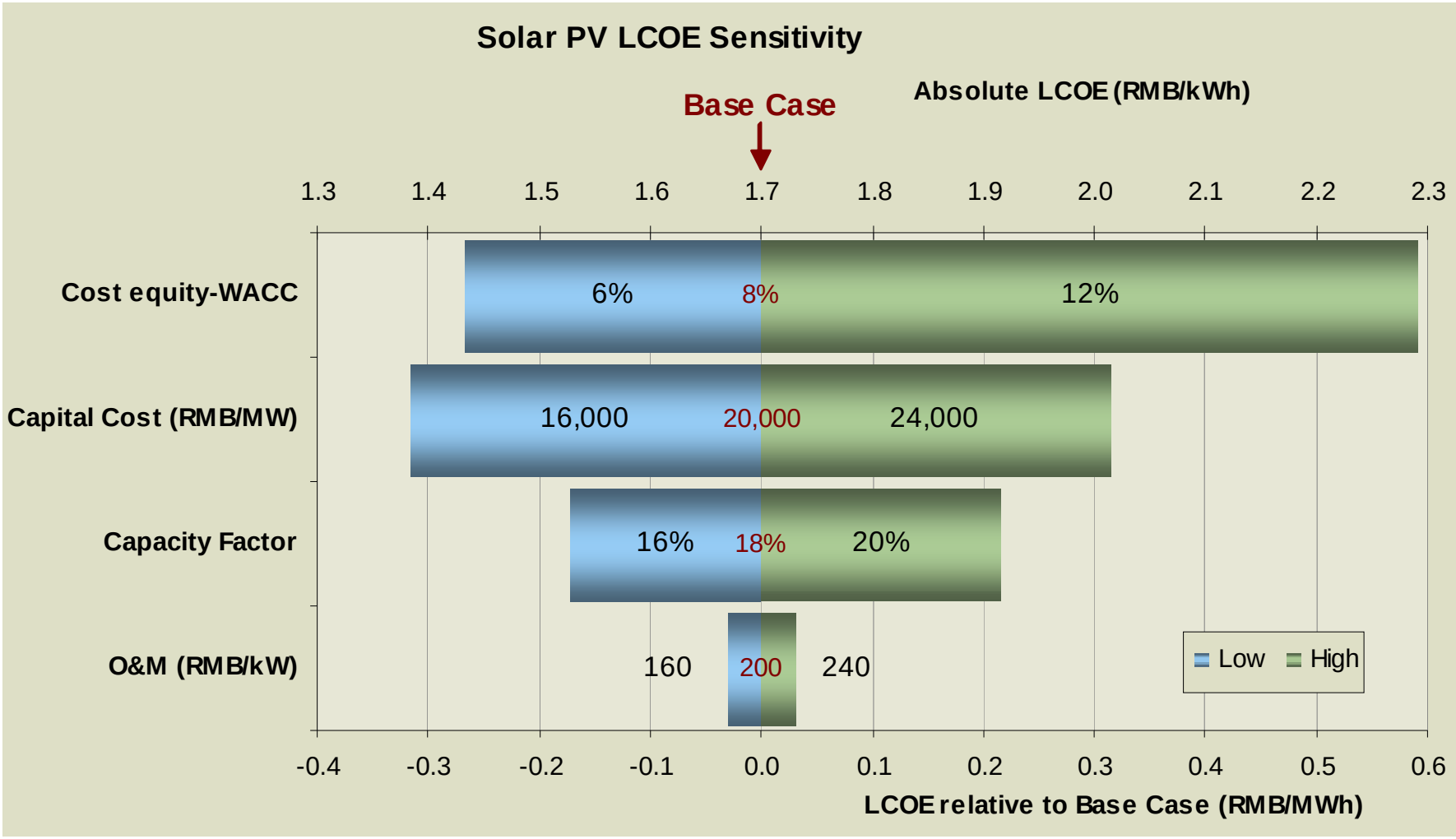
Sensitivity of LCOE to Assumptions

- LCOE of renewable energy can be highly sensitive to input assumptions
- Different assumptions can change LCOE by 50% or more. Some of the key assumptions are:
  - Capacity factor (performance)
  - Weighted Cost of capital (WACC)
  - Capital cost
- Important to select assumptions in a consistent manner across technologies

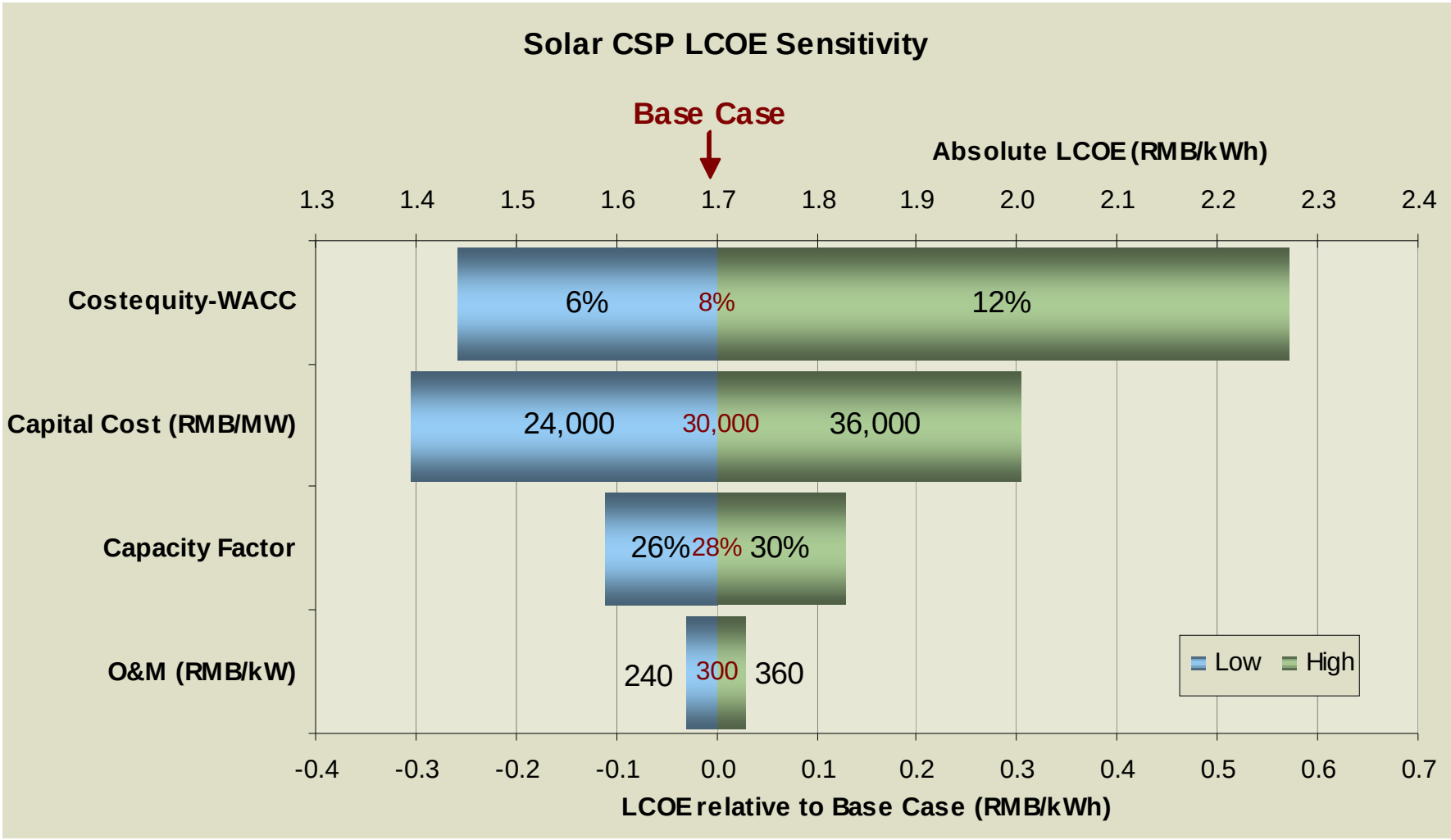
Sensitivity of LCOE (Busbar Cost) to Assumptions for Wind



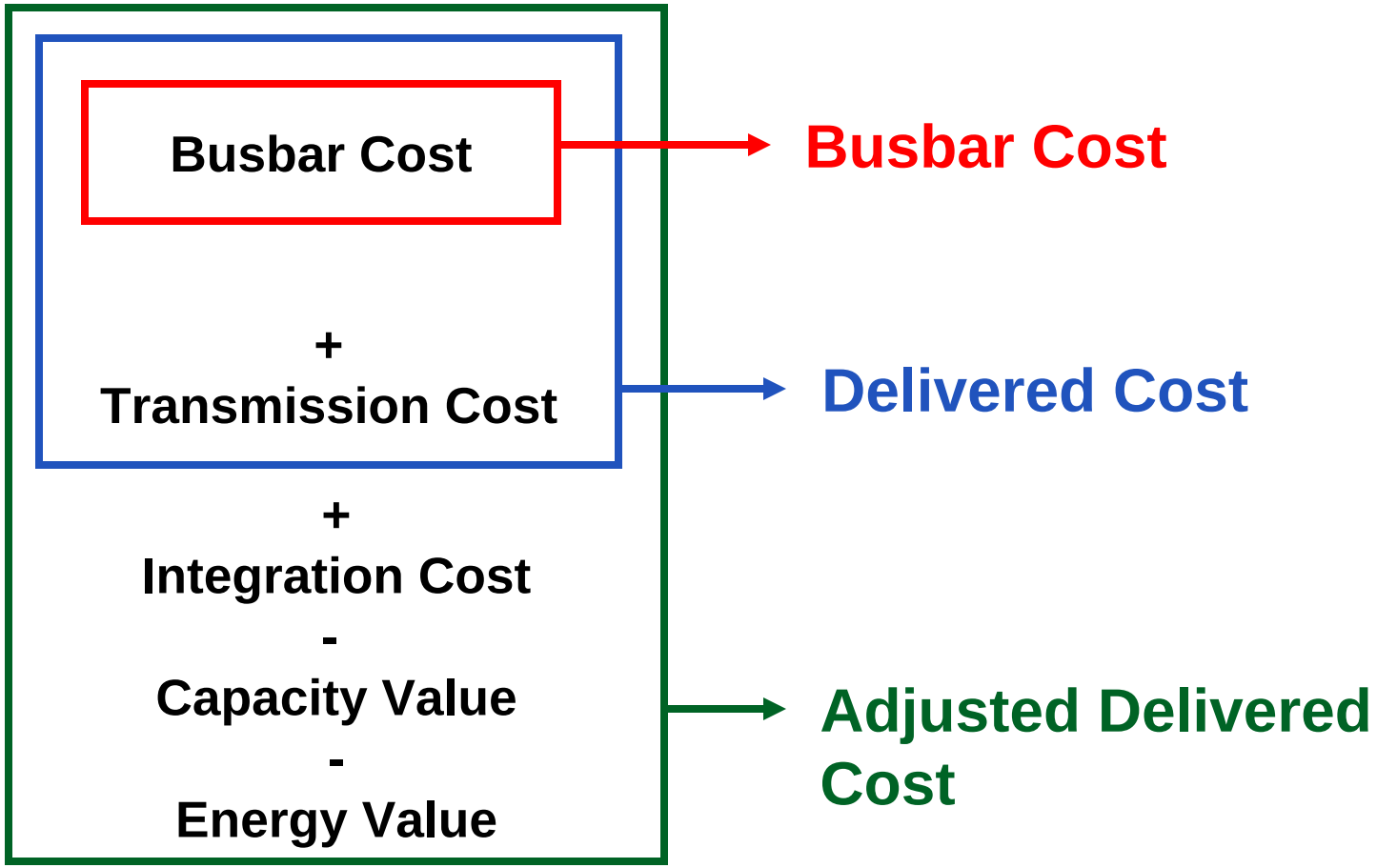
Sensitivity of LCOE (Busbar Cost) to Assumptions for Solar PV



Sensitivity of LCOE (Busbar Cost) to Assumptions for Solar CSP



Cost vs. Value Concepts for LCOE



Summary

- LCOE is the **constant unit cost** (per kWh or MWh) of a payment stream that has the same **present value** as the total cost of a generating plant over its life.
- There are multiple ways to calculate LCOE, depending on the level of financial detail
- LCOE can be Real or Nominal
- Establishing boundaries of each system for assumptions is important
- Assumptions can have significant impact on the resulting LCOE, so consistent assumptions across technologies are important