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

LCOE Range based on Capacity Factor Range

- Wind - Onshore
- Wind - Offshore Deep
- Wind - Offshore Shallow
- Solar PV
- Solar Thermal

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

Levelized Cost of Energy (RMB/kWh)

- Solar Thermal
- Solar PV
- Wind - Offshore Deep
- Wind - Offshore Shallow
- Wind - Onshore

0.5 1 1.5 2
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 \( s\text{LCOE} \) is the minimum price at which energy must be sold for an energy project to break even (or have present value of zero)

\[
s\text{LCOE} = \frac{[(\text{capital cost} \times \text{CRF}) + \text{fixed O&M cost}]}{(8.76 \times \text{capacity factor})} + (\text{variable O&M cost} \times \text{output})
\]

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.

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)

![Nominal vs. Real LCOE](chart.png)

- **Nominal LCOE**
- **Real LCOE (2010 RMB)**
- **Real LCOE with Inflation (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

- 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)

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

<table>
<thead>
<tr>
<th></th>
<th>Capital Cost (RMB/kW)</th>
<th>O&amp;M (RMB/kW-yr)</th>
<th>Capacity Factor</th>
<th>LCOE (RMB/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Onshore Wind</strong></td>
<td>9,000</td>
<td>250</td>
<td>40%</td>
<td>0.54</td>
</tr>
<tr>
<td><strong>Solar PV</strong></td>
<td>20,000</td>
<td>200</td>
<td>15%</td>
<td>1.72</td>
</tr>
<tr>
<td><strong>Solar CSP</strong></td>
<td>30,000</td>
<td>300</td>
<td>28%</td>
<td>1.66</td>
</tr>
</tbody>
</table>

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic Life</strong></td>
<td>20 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tax Life for Depreciation</strong></td>
<td>20 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>O&amp;M Escalation</strong></td>
<td>2.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Discount Rate</strong></td>
<td></td>
<td></td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td><strong>Tax Rate</strong></td>
<td></td>
<td></td>
<td></td>
<td>30%</td>
</tr>
<tr>
<td><strong>WACC</strong></td>
<td></td>
<td></td>
<td></td>
<td>8%</td>
</tr>
</tbody>
</table>
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

### Onshore Wind LCOE Sensitivity

- **Base Case**
- **Absolute LCOE (RMB/kWh)**
  - Low: 0.3
  - High: 0.8

#### Key Assumptions

- **Capacity Factor**
  - 20%
  - 30%
  - 40%

- **Cost equity-WACC**
  - 6%
  - 8%
  - 12%

- **Capital Cost (RMB/MW)**
  - 7,200
  - 9,000
  - 10,800

- **O&M (RMB/kW)**
  - 200
  - 250
  - 300
Sensitivity of LCOE (Busbar Cost) to Assumptions for Solar PV
Sensitivity of LCOE (Busbar Cost) to Assumptions for Solar CSP

### Solar CSP LCOE Sensitivity

- **Costequity-WACC**:
  - Base Case: 6%, 8%, 12%

- **Capital Cost (RMB/MW)**:
  - Base Case: 24,000, 30,000, 36,000

- **Capacity Factor**:
  - Base Case: 26%, 28%, 30%

- **O&M (RMB/kW)**:
  - Base Case: 240, 300, 360

### Absolute LCOE (RMB/kWh)
Cost vs. Value Concepts for LCOE

Busbar Cost + Transmission Cost + Integration Cost - Capacity Value - Energy Value

Busbar Cost

Delivered Cost

Adjusted Delivered Cost
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