Cost benefit analysis of HELE and Subcritical coal fired electricity generation technologies in Southeast Asia

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Overview

1) Background
2) The Challenge
3) Methodology
4) Results
5) Conclusion
Background
Coal fired electricity generation

- Coal fired electricity generation with a total capacity of 1700 GW account for 41% of electricity generation worldwide.

- Responsible for over 28% of global CO2 emissions

- Responsible for global warming and associated with devastating public health and environmental impacts.

- Several coal user countries have been working on their national plans to kick in global efforts to reduce CO2 emissions from their electricity generation sectors through development and deployment of HELE coal fired power generation technologies.
HELE efficiency ratings, emission reductions, and CCS savings

Table I. HELE technologies: Low heating value (LHV) based efficiency improvements, intensity factors and fuel consumption [19].

<table>
<thead>
<tr>
<th></th>
<th>Efficiency rate (%) net LHV basis</th>
<th>CO₂ intensity (CO₂/kWh)</th>
<th>Coal consumption (g/kWh)</th>
<th>Steam temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-USC</td>
<td>45-50%</td>
<td>670-740</td>
<td>290-320</td>
<td>700</td>
</tr>
<tr>
<td>USC</td>
<td>Up to 45%</td>
<td>740-800</td>
<td>320-340</td>
<td>600</td>
</tr>
<tr>
<td>SC</td>
<td>Up to 42%</td>
<td>800-880</td>
<td>340-380</td>
<td>Approx. 550-600</td>
</tr>
<tr>
<td>Subcritical</td>
<td>Up to 38%</td>
<td>≥ 880</td>
<td>≥ 380</td>
<td>&lt;550</td>
</tr>
</tbody>
</table>
The 2DS Scenario

Figure 1  Electricity generation from different coal-fired power technologies in the 2DS


Note: Carbon capture is integrated with HELE coal-fired units to minimise coal consumption and CO₂ abatement cost.
Necessity of HELE technology pathway

- Coal is the largest source of electricity generation.
- Installed capacity to increase around 160 GW by 2040.
- Coal generation will overtake gas by 2040.
- Coal will provide 40% of electricity generation by 2040.

- There is a regional understanding among ASEAN nations that growing use of coal will necessitate a HELE technology energy pathway.
The Challenge and Motivation
• HELE coal-fired technologies are expensive to build.
• High cost is the main restriction element for large scale deployment.
• Subcritical technology have been traditionally preferred due to their low upfront costs and shorter lead time.
• It is highly likely that project developers end up accepting lower efficiency and poor emission rates from sub-critical coal fired technology.

• To decarbonize electricity sector by 2050 under 2DS, subcritical pants need to be completely phased out by 2050.
• Following 2020, more efficient CCS and HELE coal fired power plants are to be employed.
• IEA thus recommends national energy plans and policies to rapidly phase out construction and deployment of subcritical stations.

• Progress on current deployment of HELE coal fuelled facilities is slow and subcritical units are still being deployed.
Methodology
Levelized cost of electricity (LCOE) generation

• The LCOE metric considers project’s overall expected lifetime costs (including construction, fuel, financing, maintenance, insurance, taxes, and incentives), which are then divided by project’s lifetime expected power output (kWh).

• THE LCOE ins US$ per megawatt-hour(US$/MWh) is calculated

\[
LCOE = \frac{CAPEX \times FCR + O & M_{fixed}}{CF \times 8760} + O & M_{variable} + \Pi_{fuel} \times HR + R_C \times C_C
\]
Levelized cost of electricity (LCOE) generation

\[ LCOE = \frac{CAPEX \times FCR + O & M_{\text{fixed}}}{CF \times 8760} + O & M_{\text{variable}} + \Pi_{\text{fuel}} \times HR + R_C \times C_C \]

- **FCR** is the fixed charge rate (US$/MWh), or in other words, the amount of revenue per dollar of investment required that must be collected annually from customers to pay the carrying charges on the investment;
- **CAPEX** is the capital expenditure. There are no publicly available CAPEX data sets for ASEAN countries. For our analysis, these figures are therefore replaced with engineering, procurement and construction (EPC) costs in which other costs may incur additionally such as land cost, cost of any additional emission controls, and other financing cost;
- **O & M_{\text{fixed}}** is the fixed operation and maintenance (O&M) cost (US$/MWh);
- **CF** is the capacity factor. It is a fraction between 0 and 1 representing the total generation of a plant as proportion to its nameplate capacity;
- **8760** is the number of hours in a year;
- **O & M_{\text{variable}}** is variable O&M cost (US$/MWh);
- **\Pi_{\text{fuel}}** is the fuel price (US$/GJ (US$/MMBtu));
- **HR** is the heat rate (GJ/MWh (MMBtu/MWh));
- **R_C** is the emission rate (ton/MWh); and
The four scenarios

- **Scenario 1 (Base Scenario)**
  - Assumes no future for carbon pricing and no controls over NOx and SOx emissions in Southeast Asia.
  - LCOE analysis is simply based on base plant EPC, O&M, fuel costs, and financing costs.

- **Scenario 2 (Climate change mitigation scenario)**
  - We assume a small price of US$ 10/ton as a shadow price on carbon for the achievement of low emissions to help limit global mean temperature under 2DS.

- **Scenario 3 (Pollution Control Scenario)**
  - This scenario adds the cost of deSOx and deNOx facilities to the respective coal-fired plants in our analysis.

- **Scenario 4 (Climate change mitigation and pollution control scenario)**
  - Under this scenario, the costs of deSOx and NOx facilities and carbon pricing are thus integrated in the overall costs of coal-fired plants.
Assumptions

Table 2. HHV based coal-fired power plant efficiencies and heat rates.

<table>
<thead>
<tr>
<th></th>
<th>Efficiency rate (% net HHV basis)</th>
<th>Heat Rate of fuel [Btu/kWh] (HHV basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-USC</td>
<td>47%</td>
<td>7259.57 [Btu/kWh]</td>
</tr>
<tr>
<td>USC</td>
<td>42%</td>
<td>8123.81 [Btu/kWh]</td>
</tr>
<tr>
<td>SC</td>
<td>39%</td>
<td>8748.72 [Btu/kWh]</td>
</tr>
<tr>
<td>Subcritical</td>
<td>35%</td>
<td>9748.57 [Btu/kWh]</td>
</tr>
</tbody>
</table>

Table 3. General assumptions for cost benefit analysis.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Values</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capacity</td>
<td>1,000 MW</td>
</tr>
<tr>
<td>Operation</td>
<td>20, 25 years</td>
<td>For cash flow purposes</td>
</tr>
<tr>
<td>Operation rate</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td>47% (A-USC), 42% (USC), 39%</td>
<td>HHV based values. A 3% decrease in thermal efficiency is assumed.</td>
</tr>
<tr>
<td>efficiencies</td>
<td>(SC), 35% (subcritical)</td>
<td></td>
</tr>
<tr>
<td>Annual</td>
<td>7,008 GWh</td>
<td></td>
</tr>
<tr>
<td>generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>Heating value</td>
<td>4,000 kcal/Kg or equivalently 1008.656 Btu/Kg</td>
</tr>
<tr>
<td>specifications</td>
<td>CO$_2$ emissions</td>
<td>1.43 kg CO$_2$/kg coal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Based on IPCC 2006 default emission for stationary combustion in the energy sector [31].</td>
</tr>
</tbody>
</table>
### Assumptions

**Table 4. LCOE breakdown costs.**

<table>
<thead>
<tr>
<th>LCOE</th>
<th>Base plant</th>
<th>EPC</th>
<th>O&amp;M</th>
<th>Fuel cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>deSOx</td>
<td></td>
<td>EPC</td>
<td>O&amp;M</td>
<td></td>
</tr>
<tr>
<td>deNOx</td>
<td></td>
<td></td>
<td></td>
<td>Additional fuel cost</td>
</tr>
<tr>
<td>Financing</td>
<td></td>
<td>Interest Rate of Return (IRR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td></td>
<td>Carbon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results
**Figure 3.** Scenario 1 Sensitivity Analysis of LCOE for different coal prices and economic life span of the subcritical and HELE plants.
Figure 4. Scenario 2 Sensitivity Analysis of LCOE for different coal prices and economic life span of the subcritical and HELE plants.
**Figure 5.** Scenario 3 Sensitivity Analysis of LCOE for different coal prices and economic life span of the subcritical and HELE plants.
Figure 6. Scenario 4 Sensitivity Analysis of LCOE for different coal prices and economic life span of the subcritical and HELE plants.
Figure 7. Scenario 1 LCOE differences between HELE and subcritical technologies for different coal prices and economic life span of the plant.
Figure 8. Scenario 2 LCOE differences between HELE and subcritical technologies for different coal prices and economic life span of the plant.
**Figure 9.** Scenario 3 LCOE differences between HELE and subcritical technologies for different coal prices and economic life span of the plant.
Figure 10. Scenario 4 LCOE differences between HELE and subcritical technologies for different coal prices and economic life span of the plant.
Conclusion
• The pollution control scenario (i.e., implementation of carbon pricing policy) surpasses the other scenarios in displacing subcritical plants sooner than earlier to pave the way for HELE technologies.

• Reduced coal prices and increased life spans benefit both HELE and subcritical coal-fired power plants.

• HELE coal-fired power plants are economically competitive against subcritical plants.

• A-USC coal-fired power plants are the most economically attractive choice for deployment in Southeast Asia, followed by USC, and SC plants.

• In the short run the Southeast Asian economies should focus on devising and implementing carbon pricing to support quicker deployment of HELE and displacement of subcritical technologies.

• Ultimately, in the log-run, a strong carbon price signal will be needed with strict emission standards to enable HELE transition.
Questions??
Thank You