Valuing Energy Security –
Quantifying the Benefits of Operational and Strategic Flexibility
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4 October 2013
We at The Lantau Group are experts in the economics of energy systems.
Overview

1. What exactly is energy security?
2. Is fuel diversity valuable?
3. Is strategic flexibility important?
Energy security is one leg of the “trilemma” that appears in energy policy discussions for many countries.
The concept of energy security is seemingly simple…

An electricity system that embodies a high degree of energy security will be resilient to exogenous physical and financial disruptions.
So much has been written on the topic of ‘energy security’ – but so little of it is useful policy guidance.

- Attempts to quantify “energy security” so as to rank countries: 90 percent
- Attempts to provide useful policy guidance: 10 percent
- Drivel: 90 percent
- Useful: 10 percent
The useful literature recognizes that energy security risks take different forms – and must be analyzed and addressed separately.

<table>
<thead>
<tr>
<th>Energy Security Risk Matrix</th>
<th>Physical (supply shortfall)</th>
<th>Financial (high prices)</th>
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</thead>
<tbody>
<tr>
<td><strong>Short-Term</strong></td>
<td>• Technical failure</td>
<td>• Supply disruption</td>
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<td></td>
<td>• Extreme weather events</td>
<td>• Cartel production quota</td>
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<td>• Political disruption</td>
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<td><strong>Long-Term</strong></td>
<td>• Resource depletion</td>
<td>• Fuel price shifts</td>
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<td>• Resource nationalization</td>
<td>• New technologies</td>
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<td>• Policy/regulatory failure</td>
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Each class of risk can best be managed via different strategies.

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<td><strong>Short-Term</strong></td>
<td>• Physical redundancy</td>
<td>• Bilateral contracts</td>
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<td></td>
<td>• Supplier diversity</td>
<td>• Hedging instruments</td>
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<td></td>
<td><strong>Long-Term</strong></td>
<td><strong>Clear policy guidance</strong></td>
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<td></td>
<td>• Prudent planning</td>
<td>• Strategic flexibility</td>
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<td></td>
<td>• <strong>Clear policy guidance</strong></td>
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Clear policy guidance requires a value-based framework.

But this requires an approach to valuing energy security.
Overview

1. What exactly is energy security?
2. *Is fuel diversity valuable?*
3. Is strategic flexibility important?
Much of the energy security literature is intertwined with discussions of "diversity" – but diversity itself is not a source of value

• Fuel diversity lowers risk via the “portfolio effect” – a basket of fuels will have lower overall price risk than a single fuel
  – But contracts and hedging instruments already exist to mitigate short-term volatility
  – Long-term correlation between fuel prices in international markets is very high
  – What long-term risks are we worried about anyway – since it is virtually impossible (and probably not desirable) to decouple from international energy prices in the long run?

• An electricity system incorporating fuel diversity can reap the benefits of operational (dispatch) flexibility – that is, the ability to burn the least expensive fuel at any time
  – Reaping operational flexibility benefits requires that fuel prices be free to float and quantities variable (that is, no binding take-or-pay constraint) so that such dispatch opportunities arise
  – The primary fuel competition today in Asia is between gas and coal – whose prices are so far apart as to create relatively few opportunities to realize the benefits of dispatch flexibility
  – Strategic flexibility can reap the benefits of long-term relative shifts in fuel prices

• Separately, physical redundancy or supplier diversity can offer value through lower probabilities of physical failure
Diversity advocates point to fuel-diverse systems as examples of good public policy – but fail to recognize that diversity often results from strategic flexibility.
For example, CLP (Hong Kong) has a diverse fuel mix that resulted from a series of purely economic decisions made at various points in time.

Fuel diversity could well be an outcome, it should not be a goal.
The relative coal versus crude prices illustrate the impacts of commodity price uncertainty – and stock returns are another good example.

Positive Returns

Negative Returns

Z-Score

Daily returns of an investment in the S&P 500 expressed for each day as the number of standard deviations from the average daily return since 1950.

Uncertainty is a reality in the market! Good decisions must account for uncertainty…
This uncertainty gives rise to the value of operational and strategic flexibility.

**Fuel price changes driven by uncertainty**

- Changing dispatch decisions (such as merit order) 
  \[ s.t. \text{ system constraints} \]

**Other cost changes driven by uncertainty**

- Changing optimal capacity expansion plan  
  \[ s.t. \text{ system constraints} \]

**Operational flexibility**

**Strategic flexibility**
Strategic flexibility implies that entry decisions accommodate the dynamic fuel markets.
Overview

1. What exactly is energy security?
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We analyze the benefits of diversity using a value-based framework, driven by the consideration of system cost uncertainty.

Risk is defined as the extent to which investment in a given technology increases (or decreases) the variance in cost relative to the least-cost system.
We actually use two different approaches to analyze the impacts of uncertainty.

**Screening curve analysis**
- Considers uncertainty at a point in time
- Easier to analyze and understand
- Does not account for existing system
- And fails to capture the impact of risk premium and investment “mistakes”

**Stochastic optimization**
- Models evolution of uncertainty over time
- Harder to analyze and understand
- Incorporates existing system effects
- Also captures the impact of risk premium and investment asymmetry
Traditional screening curve analysis compares the costs of alternative technologies at different capacity factors to determine preferred technologies.

Option A has lower fixed costs, but higher variable costs, so at low capacity factors it has the lowest LRMC.

Option B has higher fixed costs, but lower variable costs, so at sufficiently high capacity factors there is enough higher LRMC at low capacity factors because there is less output across which to amortize the fixed costs.

Optimal choice for capacity of a given capacity factor:

- **Option A**: Lower fixed costs, higher variable costs.
- **Option B**: Higher fixed costs, lower variable costs.

The graph shows the LRMC vs. Annual Capacity Factor for both options.
The cross-over in the screening curves determines the capacity factor at which one technology yields to another – and thereby the optimal mix.

Comparing the screening curves and the load-duration curve gives the optimal capacity mix if the system were perfectly flexible.

In this example about ninety percent of the capacity should be B (and the remainder A).
Representative fuel price and technology cost/performance scenarios that span the range of possibilities are then used to drive the model.
If we look at a ‘time slice’, these scenarios imply cumulative distributions on the various fuel prices

![Cumulative frequency distribution of fuel prices](image-url)
This structure yields a probabilistic optimal mix in which each technology has some likelihood of being the least-cost unit at a given capacity factor.
The system average cost for the incremental capacity is lowered by strategic flexibility – the opportunity to harness the least-cost mix of technologies/fuels.

But this analysis assumes perfect strategic flexibility – which overstates the realistic value.
This stochastic optimization accounts for the impact of “investment asymmetry” and “out-of-the-money technology options”

**Coal: Capital intensive**

Technologies that have lower variable costs face a relatively smaller risk of being displaced once built.

Investment asymmetry means that the investment must aim to recover more in the first year in order to break even over its life.

(Note: 25 year lifetime assumed. Final six years not shown)

Source: TLG analysis
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“Investment asymmetry” and “out-of-the-money technology options” have differential effects on alternative technologies.

Gas: Higher variable cost

Technologies that have higher variable costs face a much larger risk of being displaced.

Lower capital cost results in lower “investment asymmetry premium.”

(Note: 25 year lifetime assumed. Final thirteen years not shown)

Source: TLG analysis
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In our example, coal investments tend to reduce system costs but increase the deviation from a perfectly flexible system – thereby increasing risk.
The net effect is a preferential shift towards less capital-intensive technologies.

- Increased capital recovery requirements in earlier years means that less coal capacity tends to be built.
- Lower capital intensive technology options tend to offer greater strategic flexibility to change the future capacity expansion plan.
Using this framework, we can value flexibility – the value of strategic flexibility is comparable to that of operational flexibility.

Illustrative example: Expected PV of system costs

Percent of deterministic case

- Probabilistic Dispatch and Capacity Expansion: 86%
- Value of strategic flexibility: 6%
- Probabilistic Dispatch: 92%
- Value of operational flexibility: 8%
- Deterministic Dispatch and Capacity Expansion: 100%
Implications of “trilemma” value framework

• Expanding the opportunity to profit from strategic flexibility has great value
  – Investments in infrastructure that expand the scope of technology/fuel options are valuable
  – But long-term take-or-pay contracts that force utilization of such infrastructure reduces strategic flexibility
  – Policies that create non-market constraints – such as carbon caps that preclude the use of international offsets – limit strategic flexibility
  – High-capital, low-variable cost investments offer fewer opportunities for the overall system to gain from strategic flexibility

• By itself, diversity has relatively little value
  – Incremental operational flexibility associated with diversity has relatively little value given existing fuel price expectations in SE Asia
  – Strategic flexibility can capture much of the long-term potential dispatch flexibility
  – The value of “portfolio diversification” appears to be small (on the order of a few percent of capital cost) relative to differences in long-run marginal costs
  – Hedging mechanisms exist that do not require investment in diverse resources
Thank You!

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