Thermal and Nuclear Energy Portfolio Selection using LCOE CVaR

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Project Profitability by LCOE

In corporate finance, **profitability** of an **investment project** can be assessed studying the project **cash flows**, comparing the **return rate** $r_P$ of the project with the market **cost of capital** $r_{cc}$ rate. If

$$r_P > r_{cc}$$  \hspace{1cm} (1)$$

the project is profitable.

For example, for just two flows at $t = 0$ and $t = 1$, like an initial investment cost $C_P(0) = -100$ and the revenue $R_P(1) = 110$ from its sale, if $r_P = (110 - 100)/100 = 10\% > r_{cc}$, the project is profitable.
In case of more costs \( C_P(t) > 0 \) and revenues \( R_P(t) > 0 \), a single internal rate of return \( r_{irr} \) defined implicitly from the flow as

\[
\sum_{t<0} C_P(t)/(1 + r_{irr})^t = \sum_{t\geq0} R_P(t)/(1 + r_{irr})^t
\]

can indicate profitability, when

\[ r_{irr} > r_{cc}. \]

Here again profitability is expressed in terms of rate levels.
In the case of building an energy generation plant, if the present value (PV) at operations’ starting time $t = 0$ of building costs $C_P^<(t) \ (t < 0)$ and operation costs $C_P^>(t) \ (t > 0)$ is lower than the PV of the sales revenues $R_P^>(t) \ (t > 0)$ as

$$C = \sum_{t<0} \frac{C_P^<(t)}{(1 + r_{cc})^t} + \sum_{t\geq 0} \frac{C_P^>(t)}{(1 + r_{cc})^t} \leq \sum_{t\geq 0} \frac{R_P^>(t)}{(1 + r_{cc})^t} = R,$$

the project is profitable.

Here profitability is expressed in terms of price $\times$ quantity levels

$$C \leq R$$

instead of rates $r_{cc} \leq r_P$.  

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In energy finance, the Levelised Cost of Electricity (LCOE) helps to assess a threshold for profitability of building a new plant.

Like in the case of $r_{irr}$, assuming that the proceeds come from selling at a constant price LCOE all electricity produced per period $Q^>(t)$, LCOE is implicitly defined as

$$
\sum_{t<0} \frac{C_P^<(t)}{(1 + r_{cc})^t} + \sum_{t\geq 0} \frac{C_P^>(t)}{(1 + r_{cc})^t} = \sum_{t\geq 0} \frac{\text{LCOE} \times Q^>(t)}{(1 + r_{cc})^t}.
$$
The effect of **financing** the project **by equity and debt** can be included replacing the cost of capital \( r_{cc} \) with the **weighted average cost of capital** (WACC) rate

\[
r_{wacc} \geq r_{cc}.
\]

WACC quantifies the **perception of project riskiness** by equity and bond investors.

Uncertainty about future rates is necessarily included using **discount factor expectations**

\[
F_0(t) = E\left[\frac{1}{1 + r_{wacc}}\right] \text{ at } t = 0
\]

on future WACC rates.
Then

\[
\text{LCOE} = \frac{\sum_{t<0} C_P(t)F_0(t)}{\sum_{t\geq 0} Q^>(t)F_0(t)} + \frac{\sum_{t\geq 0} C_P(t)F_0(t)}{\sum_{t\geq 0} Q^>(t)F_0(t)} = I + O
\]

where \(I\) stands for \textit{normalized} investments and \(O\) for normalized operation expenses, \textit{i.e. prices}.

If electricity can be sold at a price

\[
P_e > \text{LCOE} = I + O,
\]

the project is profitable.

Here profitability is expressed in terms of \textbf{price levels} \(\text{LCOE} < P_e\) instead of rate levels.
To simplify notation, investment costs $I$ can be absorbed in operating costs $O$, to give total price, (i.e. normalized cost)

$$\text{LCOE} = I + O = T.$$ 

Tax breaks at rate $T_0$, capital depreciation $A^>(t)$, expected real escalation rate $\gamma$ (a sort of inflation for specific costs) and expected inflation $\iota$ itself can be included in the calculation of a real LCOE.

It will also be assumed that the electricity production $Q^>(t) = Q$ is constant (or known in advance).
Making the time-varying **fuel prices** $Y(t)$ and the **$CO_2$ emission prices** $Z(t)$ explicit in costs $C_P^>(t)$,

$$LCOE = T(Y(t), Z(t)).$$

If at time $t = 0$ future was known, time series $Y(t)$ and $Z(t)$ could be inserted in $O$ to compute $C_P^>(t)$.

Practically, **expected values** $\bar{Y}$ and $\bar{Z}$ are used:

$$LCOE = T(\bar{Y}, \bar{Z}).$$

This implies that their time series are assumed to be **constant** and to have **zero volatility**.
There is a lot of well known model risk in this evaluation approach.

For example, financial modelling risk enters in the choice of $r_{\text{wacc}}$. LCOE is very sensitive to WACC choice.

Economic modelling risk enters in the choice of fuel prices expectations.

This last kind of model weakness can be exploited by the proposed method.
Assume \( \omega \in \Omega \) to be a path extraction from the event set \( \Omega \).

For a single fuel plant for example, the fuel and CO\(_2\) prices \( Y(t) \) and \( Z(t) \) can be replaced by stochastic processes \( Y_\omega(t) \) and \( Z_\omega(t) \), like geometric brownian motions or mean reverting motions with jumps, or their discrete time equivalents.

LCOE becomes a time independent stochastic variable

\[
LCOE_\omega = T(\hat{Y}_\omega, \hat{Z}_\omega).
\]

since the component stochastic processes are weighted and summed over their paths.
LCOE_ω(\hat{Y}_ω, \hat{Z}_ω) has now a **distribution, a mean** \( \mu_{\text{LCOE}} \) and a **variance** \( \sigma^2_{\text{LCOE}} \).

A mutual **dependency structure** can be chosen for \( Y_ω(t) \) and \( Z_ω(t) \), for example imposing some correlation.

Economically, this would mean a correlation between the chosen fuel price and the \( CO_2 \) price.
Discount Rate Portfolio Theory

If the project under assessment involves building a portfolio plant with two types of fuel, coal and gas, with price $X_\omega$ and $Y_\omega$, both emitting $CO_2$ at $Z_\omega$ price,

$$\text{LCOE}_\omega =$$

$$T(\hat{X}_\omega, \hat{Y}_\omega, \hat{Z}_\omega) =$$

$$w^{\text{coal}} T^{\text{coal}}(\hat{X}_\omega, \hat{Z}_\omega) + w^{\text{gas}} T^{\text{gas}}(\hat{Y}_\omega, \hat{Z}_\omega) =$$

$$w^{\text{coal}} \text{LCOE}^{\text{coal}}_\omega + w^{\text{gas}} \text{LCOE}^{\text{gas}}_\omega$$

where $w^{\text{coal}} + w^{\text{gas}} = 1$ are the invested fractions.
Under an expected electricity price $P_e$, the **project return rate** should be defined as

$$\Pi_\omega = \frac{P_e - \text{LCOE}_\omega}{\text{LCOE}_\omega} = \frac{P_e}{\text{LCOE}_\omega} - 1,$$

because LCOE is linked to a cost. LCOE$_\omega$ appears in the denominator.

The **project discount rate** is more safely defined as

$$D_\omega = \frac{P_e - \text{LCOE}_\omega}{P_e} = 1 - \frac{\text{LCOE}_\omega}{P_e}.$$

$D_\omega$ represents the discount you get now on $P_e$ investing in the project to receive $P_e$ at the end of it. For **profitability** you want this discount positive.
Markowitz theory can be applied to this energy portfolio. If you are looking for an efficient project either: for a given discount level, look for the minimum variance portfolio, or: for a given variance level, look for the maximum discount portfolio.
Factor modelling is also included in this approach. Since fuel and related $CO_2$ cost enter $LCOE_\omega$ in a linear way,

$$LCOE_\omega = U^{\text{fuel}}(\hat{Y}_\omega) + U^{\text{fuel, CO}_2}(\hat{Z}_\omega) = U_\omega^{\text{fuel}} + U_\omega^{\text{fuel, CO}_2}$$

where $U$ are normalized component costs. $U_\omega^{\text{fuel, CO}_2}$ is proportional to $\hat{Z}_\omega$ through the fuel CO$_2$ intensity $I^{\text{fuel}}$:

$$U_\omega^{\text{fuel, CO}_2} = I^{\text{fuel}} A \hat{Z}_\omega.$$

Then,

$$E[LCOE_\omega] = \mu^{\text{LCOE, fuel}} = \mu^{\text{fuel}} + \mu^{\text{fuel, CO}_2}.$$
Moreover,

\[
\begin{align*}
\text{LCOE}_{\omega}^{\text{coal}} &= U_{\omega}^{\text{coal}}(\hat{X}_\omega) + U_{\omega}^{\text{coal},\text{CO}_2}(\hat{Z}_\omega) = U_{\omega}^{\text{coal}} + U_{\omega}^{\text{coal},\text{CO}_2} \\
\text{LCOE}_{\omega}^{\text{gas}} &= U_{\omega}^{\text{gas}}(\hat{Y}_\omega) + U_{\omega}^{\text{gas},\text{CO}_2}(\hat{Z}_\omega) = U_{\omega}^{\text{gas}} + U_{\omega}^{\text{gas},\text{CO}_2}
\end{align*}
\]

so that coal and gas LCOE share a factor.
If $X_\omega$ and $Y_\omega$ are independent (then they must be independent from $Z_\omega$ too),

$$E[LCOE_{\omega}^{\text{coal}} \ LCOE_{\omega}^{\text{gas}}] = \mu_{\text{coal}} \mu_{\text{gas}} + \mu_{\text{coal}} \mu_{\text{gas,CO}_2} + \mu_{\text{coal,CO}_2} \mu_{\text{gas}} + \alpha_{\text{CO}_2}$$

where

$$\alpha_{\text{CO}_2} = E[U_{\omega}^{\text{coal,CO}_2} U_{\omega}^{\text{gas,CO}_2}] \neq 0,$$

so that

$$\text{Cov}(LCOE_{\omega}^{\text{coal}}, LCOE_{\omega}^{\text{gas}}) = \alpha_{\text{CO}_2} = A^2 l_{\text{coal}} l_{\text{gas}} \sigma^2(\hat{Z}_\omega).$$
If one of the processes is constant, for example assuming that the fuel price $N_\omega = N_0$ for nuclear plants has very small volatility, and has zero emissions ($Z_\omega = 0$),

$$\sigma_{\text{nuclear}} = 0$$

$$\mu_{\text{LCOE, nuclear}} = N$$

$$\text{Cov}(\text{LCOE}_{\text{nuclear}}^\omega, \text{LCOE}_{\text{coal}}^\omega) = 0,$$

$$\text{Cov}(\text{LCOE}_{\text{nuclear}}^\omega, \text{LCOE}_{\text{gas}}^\omega) = 0.$$
Directly form Markowitz theory, a minimum variance portfolio can be defined, having weights $w^\text{coal}_m$ and $w^\text{gas}_m$ associated with the minimum attainable variance $\sigma^2_{D,m}$ of the project discount rate. This optimal discount rate portfolio corresponds to an optimal discount rate $\mu_{D,m}$. This portfolio minimizes the scenario risk related to fuel and CO$_2$ price uncertainty. This is a new take on LCOE analysis.
Instead of using the discount rate, **LCOE itself** can be directly used in the optimization.

In this case, LCOE plays the role of the **return**, and its variance plays the role of . . . well, of the **variance**. The **minimum attainable variance** is $\sigma^2_{L,m}$, and there the **optimal LCOE** becomes $\mu_{L,m}$.

Only modification, the **efficient frontier becomes the lower one**.
Simulation of a coal or gas portfolio

The coal $X$, gas $Y$ and CO$_2$ $Z$ nominal price processes are assumed to be geometric brownian motions discretized on a yearly grid

$$dX = (\mu_X + \pi)X \, dt + \sigma_X X \, dW_X$$
$$dY = (\mu_Y + \pi)Y \, dt + \sigma_Y Y \, dW_Y$$
$$dZ = \pi Z \, dt + \sigma_Z Z \, dW_Z$$

where $\mu_X$ and $\mu_Y$ are functions of expected real escalation rates $\gamma$, $\pi = \ln(1 + \iota)$ is a function of the expected inflation rate $\iota$, $\sigma_X$, $\sigma_Y$ and $\sigma_Z$ volatilities of independent Wiener processes $W_X$, $W_Y$ and $W_Z$. 
Notice that the **real prices** follow a very simple, lognormal process

\[
    dX = \sigma_X X \, dW_X \\
    dY = \sigma_Y Y \, dW_Y \\
    dZ = \sigma_Z Z \, dW_Z
\]
The **parameters** used to wrap the price processes and compute the **LCOE** for a plant in the US are

<table>
<thead>
<tr>
<th>Units</th>
<th>Nuclear</th>
<th>Coal</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal capacity</td>
<td>MW</td>
<td>2236</td>
<td>1300</td>
</tr>
<tr>
<td>Capacity factor</td>
<td>90%</td>
<td>85%</td>
<td>87%</td>
</tr>
<tr>
<td>Heat rate</td>
<td>Btu/kWh</td>
<td>10460</td>
<td>8800</td>
</tr>
<tr>
<td>Overnight cost</td>
<td>$/kW</td>
<td>5335</td>
<td>2844</td>
</tr>
<tr>
<td>Fixed O&amp;M costs</td>
<td>$/kW/year</td>
<td>88.75</td>
<td>29.67</td>
</tr>
<tr>
<td>Variable O&amp;M costs</td>
<td>mills/kWh</td>
<td>2.04</td>
<td>4.25</td>
</tr>
<tr>
<td>Fuel costs</td>
<td>$/MMBtu</td>
<td>0.71</td>
<td>2.26</td>
</tr>
<tr>
<td>Fuel's CO$_2$ intensity</td>
<td>Kg-C/MMBtu</td>
<td>0</td>
<td>25.8</td>
</tr>
<tr>
<td>Waste fee</td>
<td>$/kWh</td>
<td>0.001</td>
<td>–</td>
</tr>
<tr>
<td>Decommissioning cost</td>
<td>$ million</td>
<td>750</td>
<td>–</td>
</tr>
<tr>
<td>O&amp;M real escalation rate</td>
<td>years</td>
<td>1.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Fuel real escalation</td>
<td>0.5%</td>
<td>0.9%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Construction period</td>
<td>years</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Operations</td>
<td>2018</td>
<td>2018</td>
<td>2018</td>
</tr>
<tr>
<td>Plant life</td>
<td>years</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Depreciation schedule</td>
<td>MACRS,15</td>
<td>MACRS,20</td>
<td>MACRS,15</td>
</tr>
</tbody>
</table>

Start of operation ($t = 0$) is 2012. Overnight costs are assumed to be uniformly distributed on the construction period. Depreciation is developed according to the MACRS.
(all **real** year 2010 costs) and

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\iota_{\text{inflation}}$</td>
<td>1.8%</td>
</tr>
<tr>
<td>WACC</td>
<td>7%</td>
</tr>
<tr>
<td>$T_c$</td>
<td>40%</td>
</tr>
</tbody>
</table>

After estimating $\sigma$ and $\gamma$ from market time series, the **parameters** for the **price processes** become

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_c$</td>
<td>0.9%</td>
</tr>
<tr>
<td>$\gamma_g$</td>
<td>1.4%</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>0.09</td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>0.16</td>
</tr>
<tr>
<td>$\sigma_{\text{CO2}}$</td>
<td>scenario for 10 yrs, then 0.15</td>
</tr>
<tr>
<td>$\mu_c$</td>
<td>$\ln(1.009)$</td>
</tr>
<tr>
<td>$\mu_g$</td>
<td>$\ln(1.014)$</td>
</tr>
<tr>
<td>$\pi$</td>
<td>$\ln(1.018)$</td>
</tr>
</tbody>
</table>
Scenario Analysis

Real LCOE distribution, for a coal and a gas plant.
For two single-fuel plants $\mu^{LCOE, \text{fuel}}$ is estimated in dollars under three CO$_2$ volatility scenarios.

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_Z = 0.2$</th>
<th>$\sigma_Z = 0.3$</th>
<th>$\sigma_Z = 0.4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu^{LCOE, \text{coal}}$</td>
<td>88.2</td>
<td>88.2</td>
<td>88.2</td>
</tr>
<tr>
<td>$\mu^{LCOE, \text{gas}}$</td>
<td>76.2</td>
<td>76.2</td>
<td>76.2</td>
</tr>
<tr>
<td>$\sigma^{\text{coal}}$</td>
<td>14.5</td>
<td>21.7</td>
<td>32.7</td>
</tr>
<tr>
<td>$\sigma^{\text{gas}}$</td>
<td>28.2</td>
<td>29.2</td>
<td>31.2</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.18</td>
<td>0.30</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Notice 1) the nonzero correlation coefficient $\rho$, due to the CO$_2$ common factor, 2) the inversion of riskiness between coal and gas as $\sigma_Z$ increases.
For one bi-fuel plant, minimum variance LCOE portfolio weights \( w^\text{coal}_m \) and \( w^\text{gas}_m \), and optimal \( \mu_{L,m} \), are estimated under three CO\(_2\) volatility scenarios.

<table>
<thead>
<tr>
<th></th>
<th>( \sigma_Z = 0.2 )</th>
<th>( \sigma_Z = 0.3 )</th>
<th>( \sigma_Z = 0.4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w^\text{coal}_m )</td>
<td>84.0%</td>
<td>70.2%</td>
<td>45.5%</td>
</tr>
<tr>
<td>( w^\text{gas}_m )</td>
<td>16.0%</td>
<td>29.8%</td>
<td>54.5%</td>
</tr>
<tr>
<td>( \mu_{L,m} )</td>
<td>86.3</td>
<td>84.6</td>
<td>81.7</td>
</tr>
<tr>
<td>( \sigma^2_{L,m} )</td>
<td>13.8</td>
<td>19.7</td>
<td>27.2</td>
</tr>
</tbody>
</table>

Notice the inversion of relative weight between coal and gas as \( \sigma_Z \) increases. Increasing CO\(_2\) volatility makes coal generation riskier.
For **one tri-fuel** plant which includes **nuclear**, the portfolio can benefit of a **risk-free** asset, with the **highest cost** (i.e. lowest rate), with an extra weight $w^{\text{nuclear}}$.

At $\mu_{L,m}$ as a reference expected LCOE, the riskiness of this nuclear LCOE portfolio is computed.
One tri-fuel plant which includes nuclear. $w_e^\text{coal}$, $w_e^\text{gas}$, $w_e^\text{nucl}$ are the efficient frontier weights.

<table>
<thead>
<tr>
<th>$\mu$ LCOE, nuclear</th>
<th>$\sigma_x = 0.2$</th>
<th>$\sigma_x = 0.3$</th>
<th>$\sigma_x = 0.4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu$ LCOE, all</td>
<td>86.3</td>
<td>84.6</td>
<td>81.7</td>
</tr>
<tr>
<td>$\sigma$ all</td>
<td>11.7</td>
<td>16.0</td>
<td>22.3</td>
</tr>
<tr>
<td>$w_e^\text{coal}$</td>
<td>39.8%</td>
<td>15.9%</td>
<td>0.0%</td>
</tr>
<tr>
<td>$w_e^\text{gas}$</td>
<td>32.6%</td>
<td>50.2%</td>
<td>71.6%</td>
</tr>
<tr>
<td>$w_e^\text{nucl}$</td>
<td>27.6%</td>
<td>33.9%</td>
<td>28.4%</td>
</tr>
</tbody>
</table>

Notice that the included coal generation goes to zero as $\sigma_Z$ increases, in contrast to gas generation which increases. Nuclear remains constant.
For a $\mu^{\text{LCOE, nuclear}} = N = 95.4$ it turns out that, as $\sigma_Z$ increases,

- same as seen for the bi-fuel plant, **model riskiness increases**,
- **but it is always lower** than the the bi-fuel case $\sigma_{L,m}^2$,
- and the **gain in risk reduction is larger and larger**.

This means that **scenario riskiness can be reduced by inclusion of nuclear generation**.

For **larger values** of $N$, this effect is weaker.
Scenario Analysis: $\sigma_{\text{CO}_2} = 0.2$
Scenario Analysis: $\sigma_{\text{CO}_2} = 0.3$
Scenario Analysis: $\sigma_{\text{CO}_2} = 0.4$
Environmental Trade-offs

Notice that **WACC** was kept constant during the analysis, and that the LCOE is strongly nonlinear in WACC levels.

WACC can include the risk perception of investors in the nuclear business.

Including **WACC** in the **scenarios** can help to understand how **two environmental risks**, the nuclear business risk and CO₂ prices volatility, **compete** in the decision of setting how much weight to give to nuclear assets in the energy portfolio, when **scenario risk minimization** is sought.
Extended Model

The US don’t have a CO$_2$ market, then a lognormal model can be safely assumed. But models of coal and gas prices can be improved.
Mean reverting log-processes are chosen for the real coal and gas prices, and jumps are included in the gas process.

\[ d\hat{X} = (\mu_X - \theta_X \hat{X}) \, dt + \sigma_X \, dW_X \]
\[ X = \exp \hat{X} \]
\[ d\hat{Y} = (\mu_Y - \theta_Y \hat{Y}) \, dt + \sigma_Y \, dW_Y + J(\sigma_J)dN(\lambda) \]
\[ Y = \exp \hat{Y} \]
\[ dZ = \pi Z \, dt + \sigma_Z Z \, dW_Z \]

These series are discretized on a monthly time grid, and assumed as models for the true price dynamics.
After estimating $\sigma$ and $\gamma$ from monthly market time series, the **monthly parameters** for the **real price processes** (which will be then subject to escalation and inflation on a monthly base) become

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_c$</td>
<td>0.0000</td>
</tr>
<tr>
<td>$\theta_c$</td>
<td>0.0000%</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>0.0121</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.2684</td>
</tr>
<tr>
<td>$\mu_g$</td>
<td>0.0292</td>
</tr>
<tr>
<td>$\theta_g$</td>
<td>0.0210</td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>0.0602</td>
</tr>
<tr>
<td>$\sigma_j$</td>
<td>0.1258</td>
</tr>
<tr>
<td>$\sigma_{CO2}$</td>
<td>scenario</td>
</tr>
</tbody>
</table>

*Scenario (but only $\sigma = 0.2$ here)*
Case $\sigma_{\text{CO}_2} = 0.2$. The LCOE distributions (horizontally flipped) develop a thick, long tail on the undesirable side (high LCOE values).
In the Mean-Stdv plane, the **efficient frontier** includes **low value** LCOE portfolios. On the tip of the Markowitz bullet, the **minimum risk portfolio**, a $w_c = 0.2885$, $w_g = 0.7115$ combination of coal and gas plants.
The minimum risk portfolio 95% VaR is $92.3, but 95% CVaR is $100.5, ten percent higher. There is a lot of downside scenario risk in the tail.
The Mean-CVaR plane reveals a reversal of situation. If tail model risk is undesirable, the best choice is an only-gas production, with a 95% CVaR of 95.0 dollars.
Conclusions

A new approach to LCOE feasibility assessment was presented. Advantages:

- In its **lognormal version** which includes the nuclear option, it allows for an analysis to explore trade-offs between economic advantages and environmental issues, form a financial point of view.

- In its **extended version**, it allows for a risk assessment about using classic deterministic LCOE analysis to decide if and what plant to build.

M. T. Hogue *A Review of the Costs of Nuclear Power Generation*, BEBR, University of Utah, 2012, and references therein