# Inter-Commodity Spreads in Energy

Crack & Spark Spreads — Concepts, Hedging, and Payoffs

Energy Derivatives — Quant Insider

2025-10-26

**Abstract**

This note gives a practical, visual guide to *inter-commodity spreads* used by energy producers and traders. We cover the crack spread (refining margin) and the spark spread (power generation margin), with clean formulas, hedging schematics, and payoff diagrams ready for risk discussions and trading playbooks.

## 1 Why Inter-Commodity Spreads?

Producers care about *margins between inputs and outputs*, not standalone prices. Spreads let you trade and hedge that margin directly:

- **Crack spread** (refiners): refined products − crude input.
- **Spark spread** (gas-fired generators): power price − fuel cost (via heat rate).

**Trader Note**

You're not calling the outright direction of oil, gas, or power. You are trading the *relationship* between them — often more stable and more closely tied to asset economics.

## 2 Spark Spread (Electricity vs. Natural Gas)

**Key Formula**

$$\boxed{\text{Spark} = P_{\text{Elec}} - \text{HR} \cdot P_{\text{Gas}}}$$

| | | |
|---|---|---|
| $P_{\text{Elec}}$: | Power price | ($\$\,\text{MWh}^{-1}$) |
| $P_{\text{Gas}}$: | Gas price | ($\$\,\text{MMBtu}^{-1}$) |
| HR: | Heat rate | ($\text{MMBtu}\,\text{MWh}^{-1}$) |

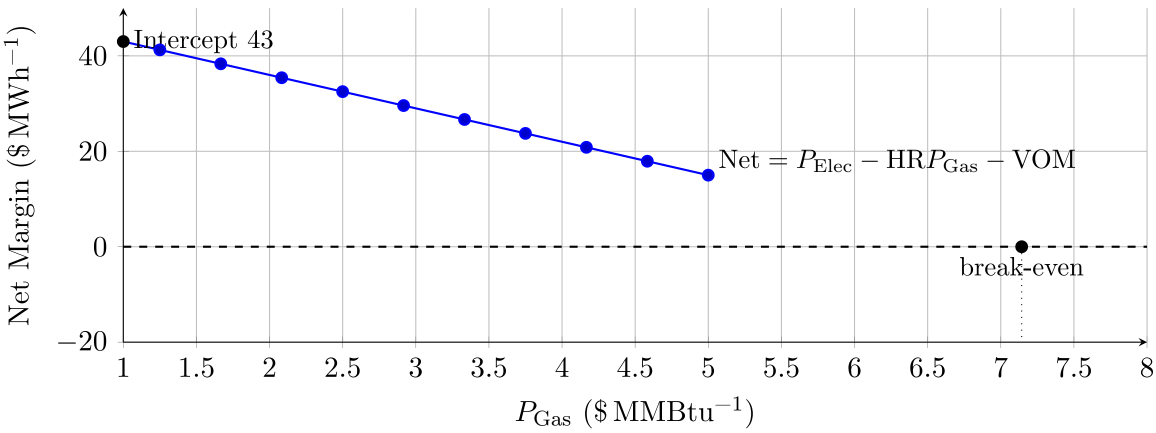
**What it means.** The spark spread measures the *gross* generation margin for a gas-fired plant: revenue from selling power minus the fuel cost required to produce it. A unit runs only if the spark spread exceeds variable O&M, so it's a direct proxy for dispatch.

### Economic intuition

- A **high** spark spread means power is rich vs. gas — generators ramp.
- A **low/negative** spark spread means the unit is out-of-the-money — it idles or buys from the grid.
- Efficiency matters: lower HR (better heat rate) $\Rightarrow$ higher margin.

### Dispatch Rule (Illustration)

Run when spark > variable cost; else idle/buy from market.




**Risk Watch**

**Key risks:** heat-rate mis-specification; location basis ($P_{\text{Elec}}$ hub vs. gas hub); shape mismatch (hourly power vs. monthly gas); outages (cannot realize physical margin).

## 3 Crack Spread (Refining Margin)

**Definition and intuition.** The crack spread is a refiner's margin: the value of products (gasoline, distillate) minus the crude input cost. It signals utilization incentives in downstream oil.

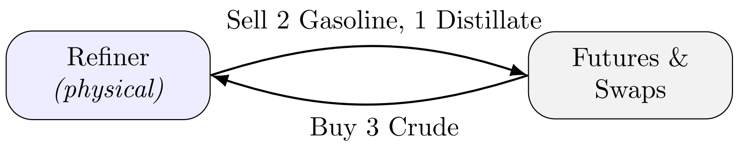
**Key Formula**

$$\text{Crack}_{3:2:1} = 2\,P_{\text{RBOB}} + 1\,P_{\text{HO}} - 3\,P_{\text{Crude}} \quad (\$\,\text{bbl}^{-1}).$$

The *3:2:1* coefficients are a stylized yield: from three barrels of crude, an average refinery produces roughly two barrels of gasoline and one of distillate.

- **Wide** crack spreads $\Rightarrow$ strong runs.
- **Narrow/negative** spreads $\Rightarrow$ reduced runs or maintenance.
- Hedge by *selling* product futures and *buying* crude futures to lock the forward margin.

### Refiner Hedge Schematic




*Lock refining margin ≈ products − crude.*

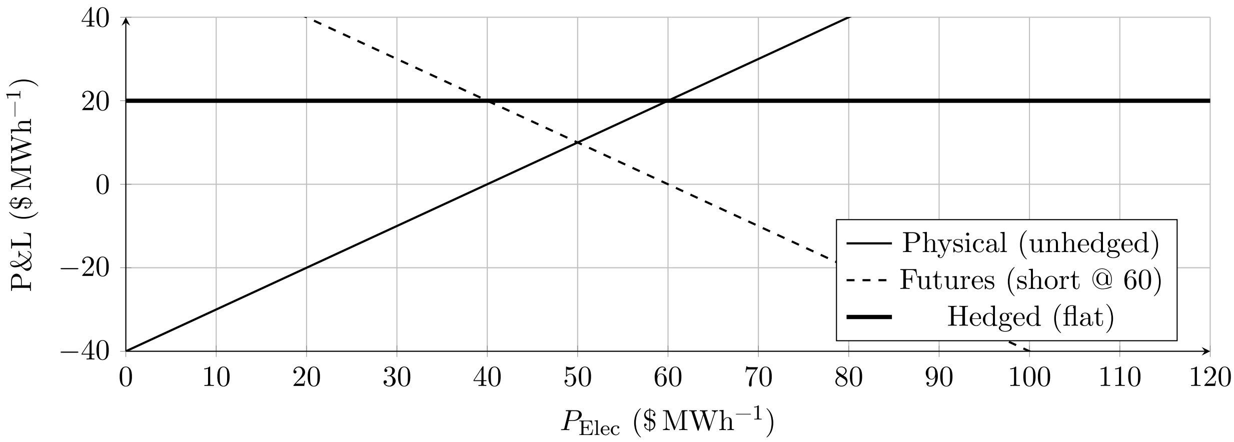
**Risk Watch**

**Key risks:** yield mismatch vs. 3:2:1 proxy; quality/location basis (WTI vs. Brent; RBOB spec); roll/term-structure effects if slate or timing shifts.

## 4 Payoff Diagrams (Hedged vs. Unhedged)

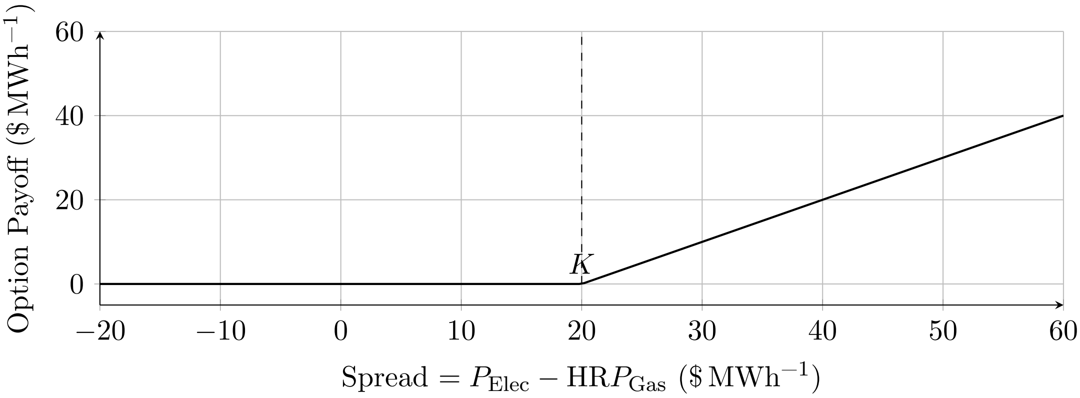
The charts show how physical P&L and futures hedges interact: unhedged profits move with price; hedges offset that slope to stabilize margin. Hedging targets *margin stability*, not elimination of all risk (basis, efficiency, outages remain).

### 4.1 Generator with Short Power Futures (Price Hedge)




### 4.2 Spark Spread Option (Call on Margin)

Payoff $\max(P_{\text{Elec}} - \text{HR}P_{\text{Gas}} - K, 0)$:




## 5 Modeling Notes (Quick & Useful)

For quick analytics, treat the spread as a linear combination of correlated prices. This yields closed-form mean/variance for risk metrics and for strike selection on spread options.

**Spark distribution (normal proxy).** If

$$P_{\mathrm{Elec}} \sim \mathcal{N}(\mu_e, \sigma_e^2), \qquad P_{\mathrm{Gas}} \sim \mathcal{N}(\mu_g, \sigma_g^2), \qquad \mathrm{corr} = \rho,$$

then

$$S \equiv P_{\mathrm{Elec}} - \mathrm{HR}P_{\mathrm{Gas}} \sim \mathcal{N}\big(\mu_e - \mathrm{HR}\mu_g,\\ \sigma_e^2 + \mathrm{HR}^2\sigma_g^2 - 2\mathrm{HR}\rho\sigma_e\sigma_g\big).$$

Useful for quick risk and strike selection.

**Crack coefficients.** 3:2:1 is a proxy. Tailor to your refinery yields and seasonal demand splits to reduce basis.

**Term structure.** Power is often shaped hourly/weekly; fuels monthly. Hedge in layers (baseload + shaped strips) to reduce residuals.

**Basis taxonomy.** Location (hub vs. hub), product spec, tenor (daily vs. monthly), and temporal (rolls) — each can dominate realized hedge error.

## Appendix: Units & Conversions

- HR in MMBtu MWh$^{-1}$; typical CCGT 6.50 MMBtu MWh$^{-1}$ to 7.50 MMBtu MWh$^{-1}$.
- 1 barrel = 42.00 US gallons; watch contract multipliers (e.g., CL 1000.00 bbl).
- Power notional over horizon $H$ (hours) and capacity $Q$ (MW): $Q \times H$ (MWh).

## Appendix: Monte Carlo for Spark Options & VaR

**Model choices.** Two common proxies for monthly forwards:

(a) **Normal proxy** (fast, closed-form on the spread): $P_{\text{Elec}} \sim \mathcal{N}(\mu_e, \sigma_e^2)$, $P_{\text{Gas}} \sim \mathcal{N}(\mu_g, \sigma_g^2)$, corr $= \rho$. Then the spread $S = P_{\text{Elec}} - \text{HR} P_{\text{Gas}} \sim \mathcal{N}(\mu_S, \sigma_S^2)$ with

$$\mu_S = \mu_e - \text{HR}\,\mu_g, \qquad \sigma_S^2 = \sigma_e^2 + \text{HR}^2\sigma_g^2 - 2\text{HR}\rho\,\sigma_e\sigma_g.$$

(b) **Joint lognormal** (more realistic for prices): simulate correlated $P_{\text{Elec}}, P_{\text{Gas}}$ from correlated normals via Cholesky, then exponentiate or evolve as GBMs for the delivery horizon.

**Spark call price (normal proxy).** If $S \sim \mathcal{N}(\mu_S, \sigma_S^2)$ and strike $K$, maturity $T$, discount $r$,

$$C_0 = e^{-rT}\Big[(\mu_S - K)\,\Phi(d) + \sigma_S\,\varphi(d)\Big], \qquad d = \frac{\mu_S - K}{\sigma_S},$$

where $\Phi, \varphi$ are the standard normal CDF/PDF.

**Worked numbers (quick sanity check).** Take $\mu_e$=60, $\sigma_e$=12, $\mu_g$=3.5, $\sigma_g$=0.8, $\rho$=0.35, HR=7, $K$=20, $r$=5%, $T$=0.25:

$$\mu_S = 60 - 7 \cdot 3.5 = 35.5, \quad \sigma_S^2 = 12^2 + 7^2 \cdot 0.8^2 - 2 \cdot 7 \cdot 0.35 \cdot 12 \cdot 0.8 = 128.32,$$

so $\sigma_S \approx 11.33$, $d = \frac{35.5-20}{11.33} \approx 1.37$, giving

$$C_0 \approx e^{-0.05\cdot 0.25}\big[15.5 \cdot 0.915 + 11.33 \cdot 0.157\big] \approx \boxed{\$15.8 \text{ per MWh}}.$$

Left-tail risk proxy: $\mathbb{P}(S < 0) = \Phi(-35.5/11.33) \approx 0.09\%$.

**Monte Carlo (joint lognormal).** Let $\boldsymbol{Z} = (Z_1, Z_2) \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$; construct $\tilde{\boldsymbol{Z}} = L\boldsymbol{Z}$ with Cholesky $LL^\top = \left(\begin{smallmatrix} 1 & \rho \\ \rho & 1 \end{smallmatrix}\right)$. For monthly forwards (one step), simulate:

$$\begin{aligned} P_{\text{Elec}}^{(i)} &= F_{\text{Elec}}\,\exp\Big(-\tfrac{1}{2}\sigma_e^2 T + \sigma_e\sqrt{T}\,\tilde{Z}_1^{(i)}\Big), \\ P_{\text{Gas}}^{(i)} &= F_{\text{Gas}}\,\exp\Big(-\tfrac{1}{2}\sigma_g^2 T + \sigma_g\sqrt{T}\,\tilde{Z}_2^{(i)}\Big), \end{aligned}$$

then payoff $\pi^{(i)} = \max(P_{\text{Elec}}^{(i)} - \text{HR}P_{\text{Gas}}^{(i)} - K, 0)$ and price $\hat{C}_0 = e^{-rT}\,\frac{1}{N}\sum_{i=1}^{N}\pi^{(i)}$.

**Variance reduction (practical).** Use *antithetic variates* ($\boldsymbol{Z}$ and $-\boldsymbol{Z}$) and a *control variate* with the normal-proxy price $C_0$ above:

$$\hat{C}_0^{\mathrm{CV}} = \hat{C}_0 - \beta\Big(\hat{C}_0^{\mathrm{proxy}} - C_0\Big), \quad \beta \approx \frac{\mathrm{Cov}(\hat{C}_0, \hat{C}_0^{\mathrm{proxy}})}{\mathrm{Var}(\hat{C}_0^{\mathrm{proxy}})}.$$

**Confidence interval.** For $N$ paths, sample std. $s_\pi$, the $100(1-\alpha)\%$ CI is

$$\hat{C}_0 \pm z_{1-\alpha/2}\, e^{-rT}\, \frac{s_\pi}{\sqrt{N}}.$$

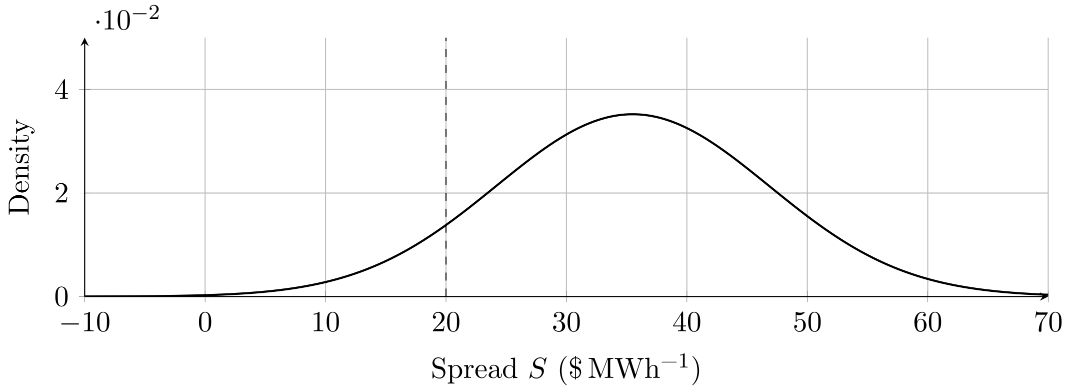
**Portfolio VaR on the spark margin.** For horizon $T$ and margin $S = P_{\mathrm{Elec}} - \mathrm{HR} P_{\mathrm{Gas}}$,

$$\mathrm{VaR}_\alpha(\mathrm{loss}) \approx -\mu_S + \sigma_S\, z_\alpha \quad (\text{normal proxy, loss } = -S).$$

For lognormal MC, compute $S^{(i)}$ and take the empirical $\alpha$-quantile of $-S^{(i)}$.

```
# Inputs: F_elec, F_gas, sig_e, sig_g, rho, HR, K, r, T, N
import numpy as np
L = np.linalg.cholesky(np.array([[1, rho],[rho,1]]))
Z = np.random.randn(2, N)
Zc = L @ Z
P_e = F_elec * np.exp(-0.5*sig_e**2*T + sig_e*np.sqrt(T)*Zc[0])
P_g = F_gas  * np.exp(-0.5*sig_g**2*T + sig_g*np.sqrt(T)*Zc[1])
payoff = np.maximum(P_e - HR*P_g - K, 0.0)
price  = np.exp(-r*T) * payoff.mean()
stderr = np.exp(-r*T) * payoff.std(ddof=1) / np.sqrt(N)
```

**Density picture (normal proxy).**




*End of note.*