The "P99 Hedge" That Wasn't

An empirical analysis of fixed quantity energy price swap performance for ERCOT wind farms

"An eye-opening examination of P99 Hedge performance. This should be required reading for anyone looking to financially hedge wind project revenues."

— **Jim Howell**
Chief Development Officer
Sustainable Power Group, LLC

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Acknowledgments

Disclosure of conflict

REsurety spends a great deal of time evaluating P99 Hedge contracts for two reasons: (1) our insurance market clients use them as a means of managing their own commodity price-driven risks, and (2) REsurety's Proxy Revenue Swap product competes with P99 Hedge contracts. Some readers might note that point #2 creates a conflict of interest as REsurety is opining on the merits of a competitive product. It is for that reason that we have exclusively focused on historical observed data, minimizing the impact of subjective forecasts or assumptions. A summary of the methodology used for our analyses is included in Annex I.

Simplifying assumption

All analyses in this white paper assume that the settlement point for any P99 Hedge and the interconnection point for all projects evaluated is the same, using the regional hub for both. In doing so, this analysis intentionally ignores the impacts of node-to-hub basis risk. This simplifying assumption is made in order to focus on the systemic issues caused by the variability of the wind as a fuel resource — and the financial impact that variability has on P99 Hedge performance — rather than on idiosyncratic transmission congestion issues.

Executive summary

A fixed quantity energy price swap, also known as a "P99 Hedge", is a useful risk management tool for wind power projects but one that results in dramatically less valuable revenues than many project developers and owners expect in their financial forecasts. Much of the overestimation of value stems from the name itself. The "P99 Hedge" name implies, incorrectly, that (1) a wind project's minimum, or "P99" quantity of energy generation has been hedged, and (2) any excess generation above P99 provides financial upside through the sale of unhedged energy at the spot market price. This interpretation of a P99 Hedge's performance is fundamentally flawed as it ignores the reality of hourly settlements, where projects with a P99 Hedge are constantly buying expensive spot market power during periods of low generation and selling cheap spot market power during periods of high generation.

To quantify the difference between the expected outcome for a typical P99 Hedge contract and the observed results, REsurety back-tested the settlement of a $22.00 per MWh P99 Hedge against the observed hourly generation of 38 wind farms in ERCOT, representing 234 cumulative years of hourly operational data. The results of that back-test show that (1) much less energy is actually hedged by a P99 Hedge than most wind projects expect and (2) the unhedged generation is worth a fraction of the spot market price of energy. As a result, this white paper demonstrates how the standard methodology used to forecast hedged revenues overestimates the observed results by 18%.

On average, wind projects with a P99 Hedge have only actually hedged 56% of the megawatt-hours of energy they generate.

Unhedged generation under a P99 Hedge has historically been 38% less valuable than the market price of energy over the same period.
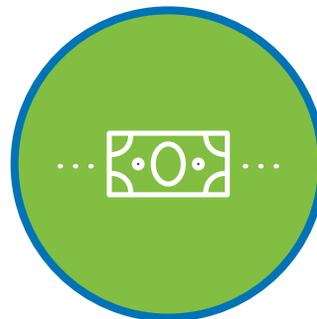
Observed hedged revenues - after P99 Hedge settlements are paid or received - have historically been 18% less valuable than expected.

The standard methodology used to forecast hedged revenues overestimates the observed results by 18%

The P99 Hedge misnomer and the resulting 80/20 Method

A fixed quantity energy price swap is often referred to as a "P99 Hedge" because the *total quantity* of energy sold at a fixed price is typically equal to the project's total annual energy generation at the expected P99 level.

Wind farms in Texas generally predict - rightly or wrongly - that their minimum quantity of annual energy generation (the "P99 Generation") is approximately 80% of their expected quantity of energy generation (the "P50 Generation"). As a result, the "80/20 Method" has emerged as a common tool for estimating the value of project revenues after settlement payments are paid to or from the wind project as a result of the P99 Hedge contract (the "Hedged Revenue"). The 80/20 Method assumes that 80% of a wind project's generation has been sold at the fixed price established in the P99 Hedge contract (the "Fixed Price"), with the remaining 20% sold, unhedged, on the spot market. Mathematically, that means that a project's expected value of Hedged Revenue (the "Expected P50 Hedged Revenue") is calculated as:

Expected P50 Hedged Revenue = **80% x P50 Generation x Fixed Price**
+
20% x P50 Generation x Market Price

The 80/20 Method is attractive for its simplicity. P50 Generation is estimated by third party wind resource assessment consultants and the Fixed Price is known from bids received from prospective P99 Hedge counterparties, so a wind project need only estimate the future generation-weighted spot market value of its power (the "Market Price") in order to calculate Expected P50 Hedged Revenue.

Unfortunately, simply looking at aggregated values grossly oversimplifies how a P99 Hedge works. A P99 Hedge is an hourly-settled contract, so the *total* quantity of energy generated, the *total* quantity of energy committed under the P99 Hedge and the *average* Market Price are irrelevant. What matters is the interplay between:
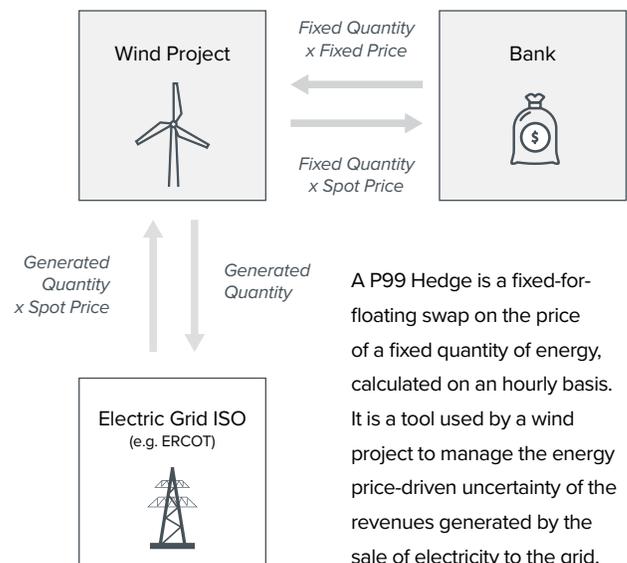1. the *hourly* quantity of energy generation,
2. the *hourly* quantity of energy committed under the P99 Hedge, and
3. the *hourly* price of energy.

What is a P99 Hedge?

Fixed quantity energy price swap (aka "P99 Hedge")

A P99 Hedge is a fixed-for-floating swap on the price of a fixed quantity of energy, calculated on an hourly basis. It is a tool used by a wind project to manage the energy price-driven uncertainty of the revenues generated by the sale of electricity to the grid.

A P99 Hedge settlement is calculated as:

$$\sum_{h=1}^{H} FQ_h * (FP - MP_h)$$

Where:
FQ_h = *Fixed Quantity of energy in hour "h"*
FP = *Fixed Price of energy contracted in P99 Hedge*
MP_h = *Market Price of energy in hour "h"*
H = *total number of hours "h" in the settlement period*

Hourly settlement: why much less energy is actually hedged than most wind projects think

When a wind project signs a P99 Hedge, it commits to selling a specific quantity of energy every hour at the Fixed Price. Note that we have intentionally used the term "sell" and not "hedge". A megawatt-hour of energy is only actually hedged under a P99 Hedge structure when it is both generated and sold at the Fixed Price in the same hour. Table 1 below illustrates this point for a hypothetical 4-hour period:

Table 1: Calculation of hedged and unhedged quantity of energy for a simulated P99 Hedge contract (all values in MWh)

Hour	(1) Generated Quantity	(2) P99 Hedge Quantity	(3) Hedged Quantity	(4) Long Quantity	(5) Non-Gen Sale Quantity	(6) Short Quantity	(7) Unhedged Quantity
1	5	20	5	-	15	-15	-
2	55	20	20	35	-	-	35
3	30	20	20	10	-	-	10
4	10	20	10	-	10	-10	-
Total	**100**	**80**	**55**	**45**	**25**	**-25**	**45**

Column 3 calculated as the minimum of i) Column 1, and ii) Column 2
Column 4 calculated as the maximum of i) Column 1 - Column 2, and ii) 0
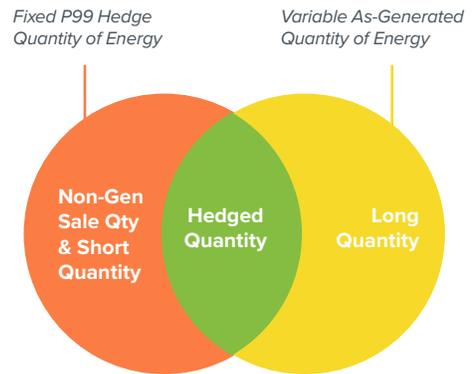*Column 5 calculated as the maximum of i) Column 2 - Column 1, and ii) 0*

Column 6 calculated as the minimum of i) Column 1 - Column 2, and ii) 0
Column 7 calculated as the sum of Columns 4, 5 and 6

Over this 4-hour example, the wind project generated 100 MWh (total of Column 1) and committed to sell 80 MWh under the P99 Hedge (total of Column 2). When considered in the aggregate, that would suggest that 80% of the project's generation had been sold at a fixed price and therefore "hedged". However, in looking at the results at the hourly level, we see a very different result.

For each hour, there are four different quantities of energy that must be considered:

- **Hedged Quantity:** includes all MWh that are both generated by the project and sold at the Fixed Price under the P99 Hedge. *(Column 3)*

- **Long Quantity:** includes all MWh that are generated by the project in excess of the P99 Hedge Quantity, which must be sold, unhedged, at the spot market price *(Column 4)*

- **Non-Generated Sale Quantity:** includes all MWh that were sold at the Fixed Price under the P99 Hedge, but for which there is no generation by the project to supply that sale. *(Column 5)*

- **Short Quantity:** includes all MWh that had to be purchased at the spot market price in order to satisfy the Non-Generated Sale Quantity. *(Column 6)*

Figure 1: Relationship of fixed and variable quantities of energy

Fixed P99 Hedge Quantity of Energy

Variable As-Generated Quantity of Energy

Non-Gen Sale Qty & Short Quantity

Hedged Quantity

Long Quantity

The results of the 4-hour illustration in Table 1 contain a critical point: despite contracting for a total volume of power under the P99 Hedge that is equal to 80% of the project's generation, in reality only 55% of the project's energy - or 55 MWh - has actually been hedged by the P99 Hedge.

The example illustrated in Table 1 is not an extreme outcome engineered to make a point. Over the 234 years of operational data from 38 wind farms REsurety reviewed in ERCOT, only 56% of the megawatt-hours generated would have been hedged under a typical P99 Hedge structure.

It is worth noting that this is not an outcome that can be meaningfully improved through better predictions of hourly generation. The wind as a fuel resource is highly volatile and always will be.

As illustrated in Figure 2 below, wind projects are constantly under or overproducing their fixed hourly P99 Hedge quantities, and by large, unpredictable amounts. As further illustration of the uncertainty of hourly generation, consider this: the correlation between the hourly quantities of a typical P99 Hedge and the hourly quantity of energy actually generated by a given project is, on average, a mere 0.28.

Figure 2: A day in the life of a P99 Hedged wind farm
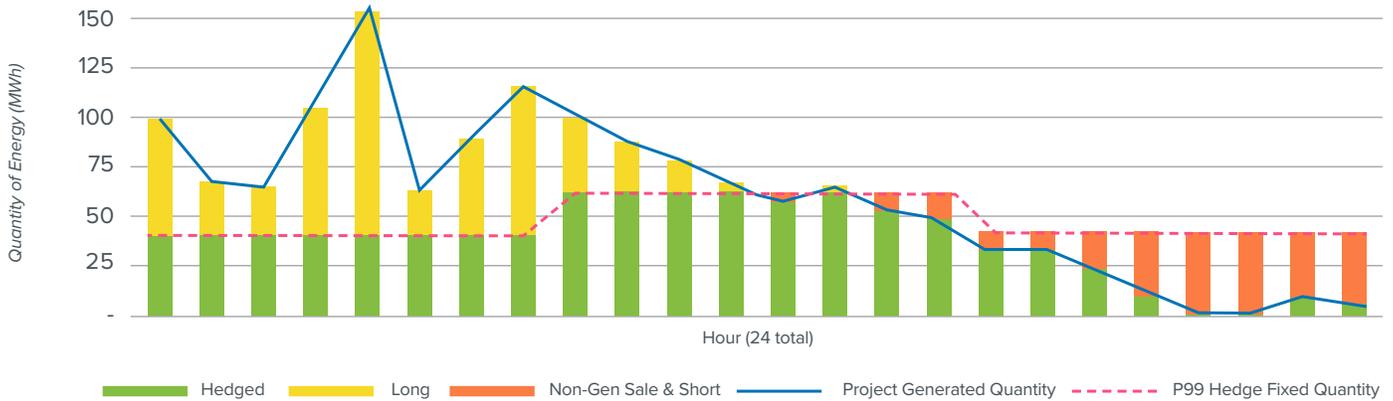
> Over the 234 years of operational data from 38 wind farms REsurety reviewed in ERCOT, only 56% of the megawatt-hours generated would have been hedged under a typical P99 Hedge structure.

Method summary:
The empirical results presented in this white paper rely on the back-testing of simulated P99 Hedge contract settlements for 38 ERCOT wind projects, each of which share the following characteristics:

- COD Date: pre-2011
- Nameplate Capacity: > 50MW
- P99 Quantity: 80% of historical average
- Merchant Settlement Point: ERCOT West, Real-Time
- Hedge Settlement Point: ERCOT West, Real-Time

See Annex I for additional details on methodology

Bad timing: why unhedged generation is worth a fraction of the Market Price of energy

A P99 Hedge results in a significant mismatch between the variable Generated Quantity of energy and the fixed P99 Hedge Quantity of energy in almost every hour of the year. Figure 2 on the previous page illustrates this point. The data are drawn from a utility-scale wind farm in Texas and represents an ordinary day.

Figure 2 shows that while a majority of MWh fall into the **Hedged Quantity** bucket – whenever the hourly Generated Quantity and P99 Hedge Quantity are equal – there are significant volumes of energy being sold to the spot market (the **Long Quantity**) and purchased from the spot market (the **Short Quantity**) in order to satisfy the **Non-Generated Sale Quantity**. The financial impact of these quantity mismatches is a function of the price of energy each hour – and how that price correlates to hours when the project is experiencing a **Short Quantity** or a **Long Quantity**, respectively.

Unfortunately, for the vast majority of energy markets, there is a strong negative (and causal) relationship between wind speed and energy price.

The result of this negative relationship is that, on average, energy prices tend to be high when wind power generation is low and prices tend to be low when generation is high. This presents a challenge for projects that sign a P99 Hedge as it means that the **Long Quantity** of energy is frequently sold during hours when energy prices are low. Further, it means that the **Short Quantity** of energy must be purchased during hours when the price of energy is high – pulling down the value of the unhedged generation. Table 2 below, which adds simulated energy prices to the quantities laid out in Table 1, illustrates this point.

Table 2: Calculation of hedged and unhedged value for a simulated P99 Hedge contract

Hour	(1) Generated Quantity (MWh)	(2) P99 Hedge Quantity (MWh)	(3) Fixed Energy Price ($/MWh)	(4) Market Energy Price ($/MWh)	(5) Hedged Value ($)	(6) Long Value ($)	(7) Non-Gen Sale Value ($)	(8) Short Value ($)	(9) Unhedged Value ($)
1	5	20	$22.00	$25.00	$110	-	$330	-$375	-$45
2	55	20	$22.00	$15.00	$440	$525	-	$0	$525
3	30	20	$22.00	$25.00	$440	$250	-	$0	$250
4	10	20	$22.00	$35.00	$220	-	$220	-$350	-$130
Total	100	80	Avg = $22.00	Avg* = $20.50	$1,210	$775	$550	-$725	$600

*Column 5 calculated as: Column 3 * the minimum of i) Column 1, and ii) Column 2*
*Column 6 calculated as: Column 4 * the maximum of i) Column 1 - Column 2, and ii) 0*
*Column 7 calculated as: Column 3 * the maximum of i) Column 2 - Column 1, and ii) 0*
*Column 8 calculated as: Column 4 * the minimum of i) Column 1 - Column 2, and ii) 0*
Column 9 calculated as: sum of Columns 6, 7, and 8

Unhedged Value per MWh*	**$13.33**
Discount below Market Price	**35%**

** Represents generation-weighted average*
** Calculated as i) the total Unhedged Value (sum of Column 9) divided by ii) the total Unhedged Quantity (sum of Column 7 from Table 1)

In this example, the project experiences a **Short Quantity** when the price of energy is high and a **Long Quantity** when the price of energy is low. As a result, the Unhedged Value per MWh over this period ($13.33) is dramatically less valuable than either the Fixed Price of the P99 Hedge ($22.00) or the Market Price of energy ($20.50).

Table 2 is, again, not an engineered result to illustrate an extreme case. Results like those shown here are common for wind projects located in regions with high installed wind generation capacity. For ERCOT West, the unhedged generation under a P99 Hedge has historically been 38% less valuable than the Market Price of energy over the same period.

High risk: P99 Hedge contracts result in a high volatility of hedged energy value

This white paper focuses on analyzing the expected value of energy generated by a wind project utilizing a P99 Hedge. While the risk associated with the resulting cash flows is not our primary focus – and could be an entire topic unto itself – it should at the very least be noted that the volatility of the hedged value of energy under a P99 Hedge is quite high. To the right, a histogram of quarterly hedged energy values observed in REsurety's review of 38 operational wind farms in ERCOT illustrates this significant volatility.

Quarterly Hedged Energy Value under $22.00 P99 Hedge ($/MWh)
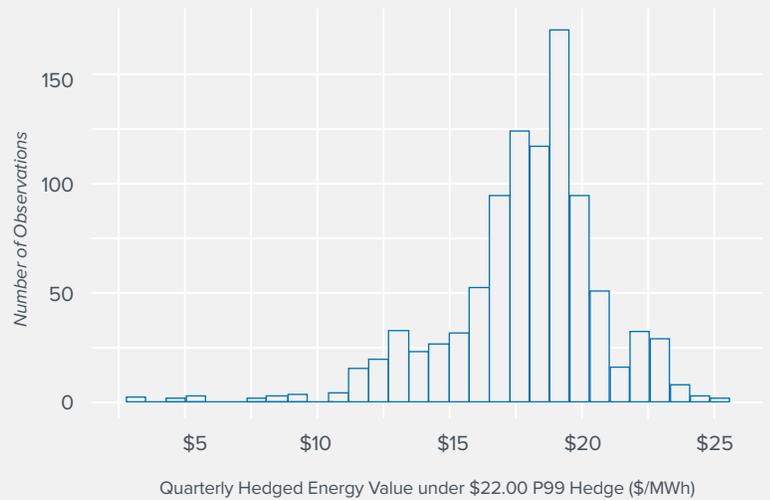
Results:

While many insights can be gleaned from a detailed review of the hourly settlements across the 38 projects analyzed, our review of the project-specific outcomes provided three key results:

Application of results:
While the exact results presented in this white paper are specific to the ERCOT West region, the general themes are not.

Similar outcomes can be seen in most regions where a significant percentage of energy consumption is served by wind power and should be expected in regions where significant development of wind generation is planned.

Result #1: Only 56% of the energy generated under a P99 Hedge structure is actually hedged

Hedged Quantity of Energy as a Percent of Total Generation (Annual)
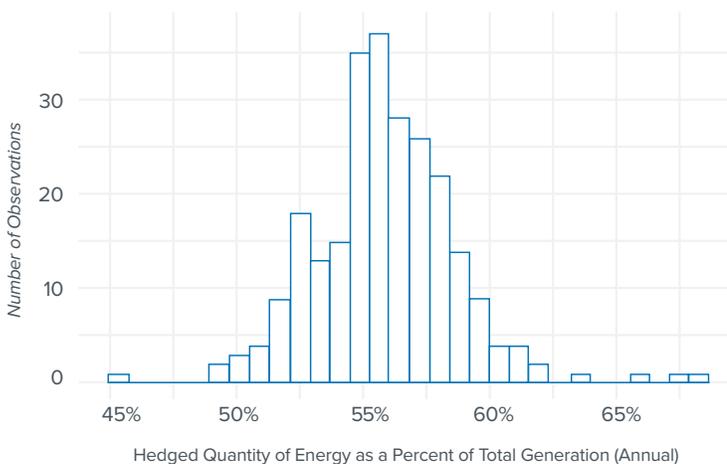
As illustrated in Table 1 of this whitepaper, the hourly mismatch of the variable Generated Quantity and the fixed P99 Hedge Quantity means that much less energy is actually hedged than the "P99 Hedge" name implies. Over the 234 operational years reviewed by REsurety, on average only 56% of the generated megawatt-hours of energy would have been hedged under a typical P99 Hedge structure.

Result #2: The unhedged generation of a wind project with a P99 Hedge has historically been 38% less valuable than the Market Price of energy over the same period

As illustrated in Table 2 of this whitepaper – the negative relationship between the hourly Generated Quantity and the hourly spot market price of energy means that the ~45% of energy generated that is unhedged under a typical P99 Hedge structure is significantly less valuable that the Market Price of energy. REsurety's review of 234 operational years in ERCOT showed this discount to be 38% on average. This significant discount off the Market Price occurs for two reasons. First, the value of the **Long Quantity** is typically lower than the Market Price as energy prices tend to be low when the quantity of wind farm generation is high. Second, the cost of the **Short Quantity** is typically higher than the value of the **Non-Generated Sale Quantity**, as energy prices tend to be high when the quantity of wind farm generation is low. As a result, the low value of the **Long Quantity** is further degraded by the net cost created by the short position.

Value of Unhedged Generation as a Percent of Market Price (Annual)
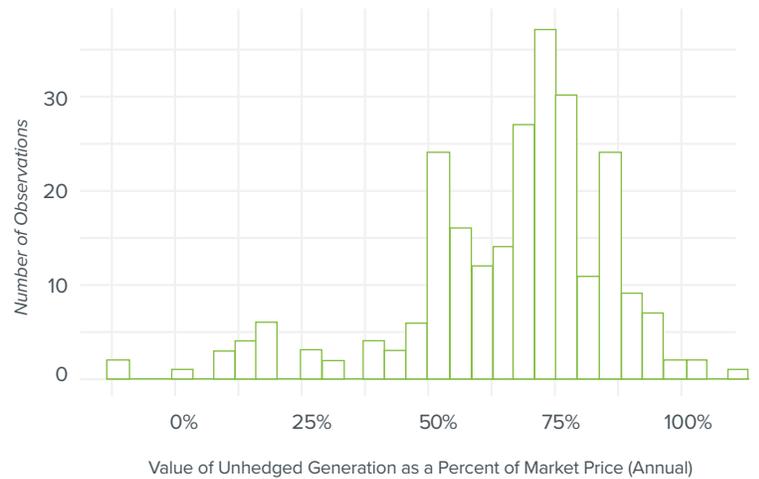
Result #3: The 80/20 Method overestimates observed Hedged Revenues by 18%

Observed Hedged Revenue as a Percent of Expected P50 Hedged Revenue (Annual)
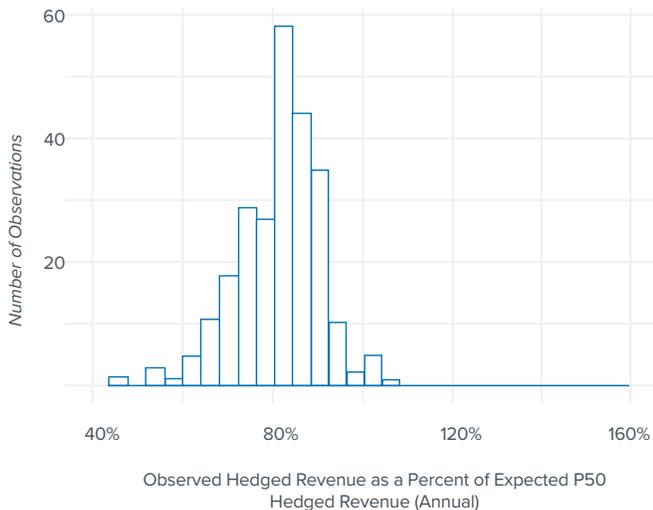
The 80/20 Method dramatically overestimates the observed Hedged Revenue results. For each of the 234 years of operational data analyzed, REsurety calculated Expected P50 Hedged Revenue as:

Expected P50 Hedged Revenue =	**$22.00 * P99 Hedge Quantity** + **20% * Observed Average Generation * Market Price**

On average, the observed annual Hedged Revenues were 82% of the Expected P50 Hedged Revenue predicted by the 80/20 Method, with a range from 46% to 106%. Only a tiny fraction (3%) of the 234 operational years reviewed by REsurety resulted in an observed Hedged Revenue that was equal to or greater than the value predicted by the 80/20 Method. It is worth pointing out that many projects predict their P99 or "worst-case" Hedged Revenue to be ~80% of their Expected P50 Hedged Revenue, meaning the observed Hedged Revenue has, on average, been fairly close to what many projects predict as their worst-case scenario.

P99 Hedges are useful tools – if accurately valued and risks understood

The analyses in this white paper may appear disparaging of P99 Hedge contracts. On the contrary – we view P99 Hedge contracts as very useful tools for managing commodity price risk exposure. However, a P99 Hedge is only a useful tool *if* its value and risks are accurately quantified and understood.

Ideally, any wind project considering a P99 Hedge will evaluate the hourly performance profile of the wind resource in its region to establish a historical relationship between hourly generation and energy price. That historical relationship can then be projected into the future, adjusting for changing fundamentals of the relevant power market – most critically the impact of additional wind generation capacity.

Whatever is decided as a method to evaluate risk and value – the authors of this white paper hope at the least that wind projects will avoid relying on the 80/20 Method. In the vast majority of markets, the 80/20 Method will result in a financial pro forma that significantly overestimates the value and significantly underestimates the risk of hedged project revenues.

> **The 80/20 Method will result in a financial pro forma that significantly overestimates the value and significantly underestimates the risk of hedged project revenues**

Connect with us!

Do you have an operational or development wind project and want to know how the analyses presented in this white paper apply to your project specifically? Energy GPS has deep expertise in providing project-specific advice on this topic. To learn more, please contact Tim Belden (tbelden@energygps.com).

Do you have an operational or development wind project with a P99 Hedge, and want to know how to manage the risk you hold as a result? REsurety offers hedging products to mitigate the residual risks held by P99 Hedged projects. To learn more, please contact Lee Taylor (ltaylor@resurety.com).

ANNEX I : summary of methods

There are about 100 operational wind farms in ERCOT representing a rich dataset with which to compare observed P99 Hedge outcomes against the Expected P50 Hedged Revenues. The following paragraphs describe the methods we relied upon to (1) filter the population of projects for only those most applicable to our analysis, (2) retrospectively structure and settle P99 Hedge contracts, and (3) predict Expected P50 Hedged Revenue values.

First, we filtered the total population of operational wind farms in order to focus only on those that provided a long, reliable and applicable history of operational data. Specifically, the following filters were employed: (1) all projects smaller than 50 MW in size were excluded, to focus on utility-scale operations; (2) projects built prior to 2005 were excluded, to focus on modern turbine technology; (3) projects built after July 2011 were excluded, to ensure a wide variety of weather and power market conditions would be represented in each project's operational history; and (4) any projects with obvious data quality issues, such as extensive periods of downtime due to site-level maintenance issues, were excluded, to focus on generalizable results rather than project-specific operations and maintenance outcomes. Lastly, projects located in southern Texas along the coast were excluded, as coastal wind projects experience a distinct wind resource compared to the rest of the state, and as such would require a separate analysis for purposes of evaluating regionally-applicable outcomes.

Having selected 38 projects for analysis, we then structured and settled a hypothetical P99 Hedge for each project. To simulate historical P99 Hedge structuring, we assumed that the quantity of energy committed under each project's P99 Hedge would be structured in monthly peak/off-peak format, with "peak" defined as the 16 hours between 6:00AM - 10:00pm Central time, seven days a week, 365 days a year. The quantity of energy committed within each monthly peak/off-peak period was set to equal 80% of the historical average observed hourly generation for each period. To simulate historical P99 Hedge settlement, a strike price of $22.00 per MWh was assumed at ERCOT West Hub Real-Time, and P99 Hedge settlements for each project were calculated at the hourly level. This strike price was determined by taking a discount of ~15% (an approximate mid-bid spread) off of the historical value of fixed volume power over the period considered in this analysis.

As a final step, we calculated the value of Expected P50 Hedged Revenue according to the 80/20 Method. For each project and for each year, this was calculated as: *$22.00 * P99 Hedge Quantity + 20% * Observed Average Generation * Market Price*. For this calculation, Observed Average Generation reflected the historical average annual generation for each project analyzed and Market Price reflected the generation-weighted price of energy for each project and for each year analyzed.

With the above calculations complete, we compared how the actual observed Hedged Revenue compared with the Expected P50 Hedged Revenue for each project-year, covering the period starting summer 2011 and ending February 2018.

Map of Analyzed ERCOT Wind Projects