



# HYBRIDISATION 2.0; WIND + FV + BESS TO MINIMIZE RISK IN THE SPANISH ELECTRICITY MARKET

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***“Hybridisation 2.0” refers to the integration of energy storage into wind projects that have already been hybridised with photovoltaic capacity. Another step to advance the energy transition in any electricity system.”***



## WIND, PV AND NOW, BESS

Combining complimentary renewable technologies at a single connection point is not a novelty and is increasingly common.

The benefits of combining two technologies – say wind and photovoltaic (“PV”) - range from a better capacity factor to a greater opportunity to sell more energy via baseload Power Purchase Agreements (“PPA”).

However, the advent of price cannibalization and curtailment, PV must find innovative configurations to ensure a return on investment while helping the power system to be more robust and lower costs.

For these reasons, among others, the hybridisation of renewables with batteries is (and should be) a growing trend, which we are calling “Hybridisation 2.0”. We are referring in particular to the integration of energy storage in wind projects that have already been hybridised with PV. Another step to advance the energy transition in any electricity system.

## WHY BASELOAD PPA?

In this type of PPA, the project developer aims to sell a project’s generation profile as baseload. Offtakers prefer baseload PPAs since they strike a balance between price and risk. In this type of PPA, the offtaker is supplied with a stable amount of energy and, although it is usually the most price-competitive financial product, it is also the one with the highest risk for the project developer since generation from renewable sources rarely matches the offtaker’s demand profile.

The prices for renewable “pay-as-produced” (“PAP”) PPAs, especially PV, tend to be well below the prices of a baseload PPA (see Figure 1), which is explained by the “duck curve” effect and a lack of consumer interest in a profile that does not match their needs. When PV and wind resources complement each other, the dispatch curve will have a more stable minimum that serves to facilitate the sale of generation via baseload PPA. And if we add batteries (“BESS”, Battery Energy Storage System), the opportunity to sign this type of PPA increases.

First, surpluses (when generation exceeds the contracted level which must be sold at the market price) fall as these can be stored in the BESS. Second, when generation falls below the contracted level, energy purchases at the market price will also be lower as any deficit can be covered with energy from the BESS. In addition, by combining the 3 technologies, more contracted MWs can be signed in baseload.

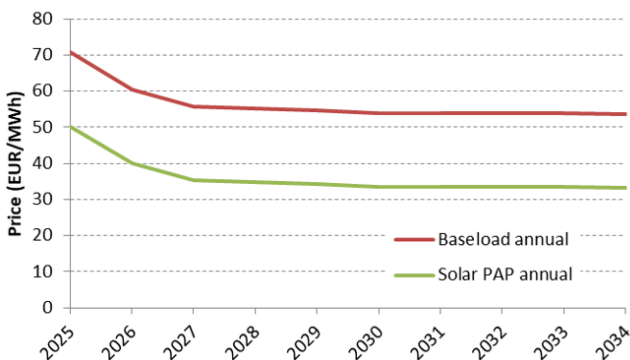


Figure 1: Baseload and PAP futures prices  
Source: OMIP, 13 September 2024.

## ADVANTAGES OVER PAP PPAs

There are several ways to carry out the incremental development of a hybridisation project (see Figure 2) but all the best ones reach an end point (green box) with Wind+PV+BESS, a single PPA baseload contract with a higher coverage than with standalone wind, and a much lower risk profile as there is less exposure to purchases when the renewable generation plus the BESS injection is less than the contracted amount.

We can show this by starting with a wind project with a baseload PPA (phase one). If it is technically feasible, it can make a lot of sense to add PV (phase two) as this helps reduce surpluses and buybacks (relative to the contracted MW in baseload). But a better solution could be to also add BESS, transferring excess generation to cover purchases and, at the same time, being able to raise the level of contracted MW in baseload PPA (phase three). And note that we would be remunerating PV generation at the higher baseload PPA price rather than the lower PAP price.

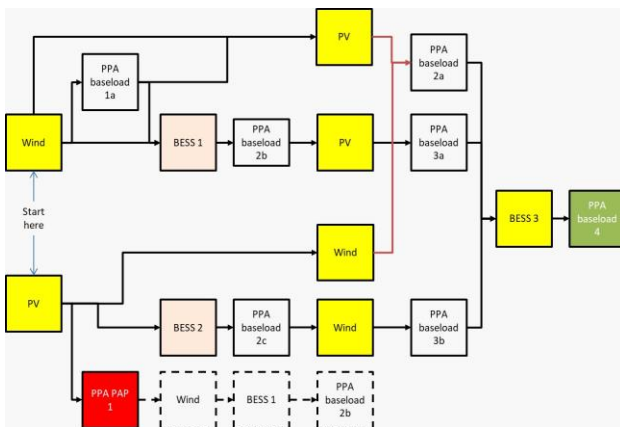


Figure 2: Wind, PV and BESS hybridisation and contracting options  
Source: K4K/EKON.

Note that the option of starting a hybridisation project with a standalone PV project and a PPA PAP contract (phase one) is a bit of a dead end. Adding Wind+BESS does not have the same impact as if the PV is uncontracted. The incremental value of expanding with Wind+BESS (phase 2) would have to be evaluated as a separate project, i.e. there is little synergy between the two phases.

One can only get to the green box if the PV is not contracted in PAP. But this raises the challenge of how to finance for the PV project (phase 1) without a PAP PPA. This conundrum could explain why wind developers seem more interested in exploring hybridisation options than PV developers.

## **MORE DISPATCH AND LESS RISK WITH HYBRIDISATION 2.0**

Although optimization appears complex, one can prepare a simple study based on public data to demonstrate the effectiveness of this Hybridisation 2.0 strategy. We used representative profile data for the same geographic location in the province of Valencia (Spain) used in first [Hybridisation 1.0 article](#).

The focus of the previous article was to illustrate the synergy between PV and wind generation curves to demonstrate that enough PV could be added to a wind plant without losing much generation when crossing the export limit to the grid determined by the existing wind capacity. Now we want to show how Hybridisation 2.0 allows us to be more aggressive in terms of contracting whilst reducing exposure to volatile market prices.

We start with a wind project with a baseload PPA. We normalize to define the maximum generation and grid injection capacity of 1MW. The baseload PPA will be for 0.5MW in each hour of the year.

Since the Renewables Ninja data gives us an Annual Capacity Factor (“ACF”) for our wind project of 35.4% (equivalent to 3,101 hours or MWh per year) and the 0.5MW contract would require an ACF of 50% (4,380 hours or MWh per year), we are going to be very short. This is reflected by the red area in Figure 3 and Figure 4 (Page 5). (These sets of three graphs are the same except that those in Figure 3 focus on the results for the first fortnight whilst Figure 4 covers all hours of the representative year). The green area shows generation above the contract level while the blue area shows generation sold under the contract. The first 2 columns of Table 1 summarise the annual results for the wind-only configuration (Page 4).

Because of the discrepancy of generation and supply, only 2,380 MWh of power generated is sold at the PPA price. The difference of 721MWh (= 3,101 - 2,380) reflects the surplus to be sold at the market price. Meanwhile, there is a shortfall requiring purchases at the market price of 2,000MWh, equivalent to 65% of annual generation. Obviously, this solution does not make much sense and explains why baseload PPA contracts for standalone wind have much lower contract cover.

By adding 1MW of PV, the second of the first three graphs shows how the red area is reduced. And what is visible in the charts is corroborated by the results in the second two columns of Table 1. Not only does the dispatch increase to 4,941MWh but the purchases also fall to 1,077MWh or 22% of annual generation. Unfortunately, we still face significant market risk as the surplus increases to 1,638 MWh or 33% of annual generation.

Finally, we add 0.5MW of BESS with 1MWh of storage capacity and assume a loss of 10% per cycle.

The algorithm for battery utilization is very simple: when there is excess energy above the contracted level this is stored until the BESS is fully charged; and, when there is a deficit relative to the contracted level, the BESS is dispatched until the contracted energy supply is satisfied or until the BESS is fully discharged. We do not need hourly prices; our focus is not optimisation via price arbitrage and the truth is that it is not necessary to identify the risk mitigation impact of this 3-in-1 configuration.

The third of the three charts indicates another clear drop in volume in the red area and this is corroborated in the numerical results shown in the third pair of columns in Table 1.

The total dispatch rises to 5,268 MWh as the sum of almost all the dispatch of the two technologies can be used. Generation covered by the PPA rises to 4096MWh or 78% of annual dispatch, whilst the deficit falls to 615MWh or just under 12% of annual dispatch. Meanwhile, surpluses also drop to more manageable 1,174MWh or 22% of annual dispatch.

## CONCLUSION

By first adding PV to wind and then BESS, we can reduce the risk of buying or selling at market price and ensure that a larger amount of generation is sold at the more favourable PPA baseload price. This is the value proposition of BESS for more conservative investors such as banks. And, separately, we are still left with the possibility of enhancing BESS returns by participating more actively in daily, intraday and ancillary service markets.

Parameter	Wind		Wind+PV		Wind+PV+BESS	
	MWh or hours	ACF <sup>1</sup>	MWh or hours	ACF <sup>1</sup>	MWh or hours	ACF <sup>1</sup>
Generation	3101	35.4%	4941	56.4%	5268	60.1%
Contracted volume	4380	50.0%	4380	50.0%	4380	50.0%
Generation sold under contract [blue]	2380	27.2%	3303	37.7%	4094	46.7%
Excess generation (sold at market price) [green]	721	8.2%	1638	18.7%	1174	13.4%
Purchases (bought at market price) [red]	2000	22.8%	1077	12.3%	615	7.0%

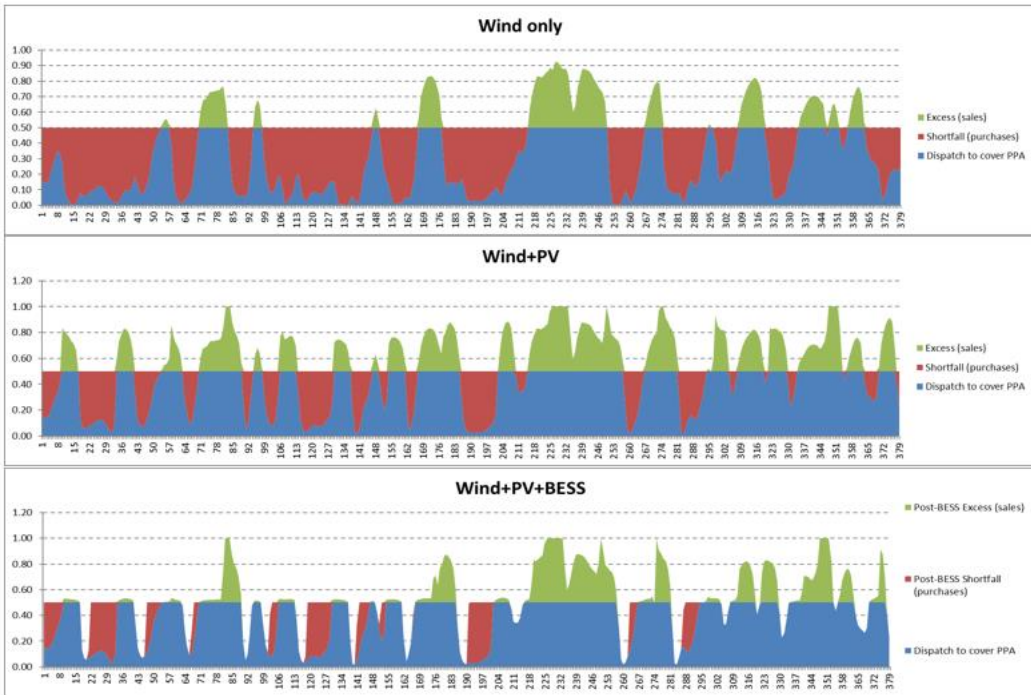
**Table 1: Simulation results.**

1: Generation or hours / 8760.

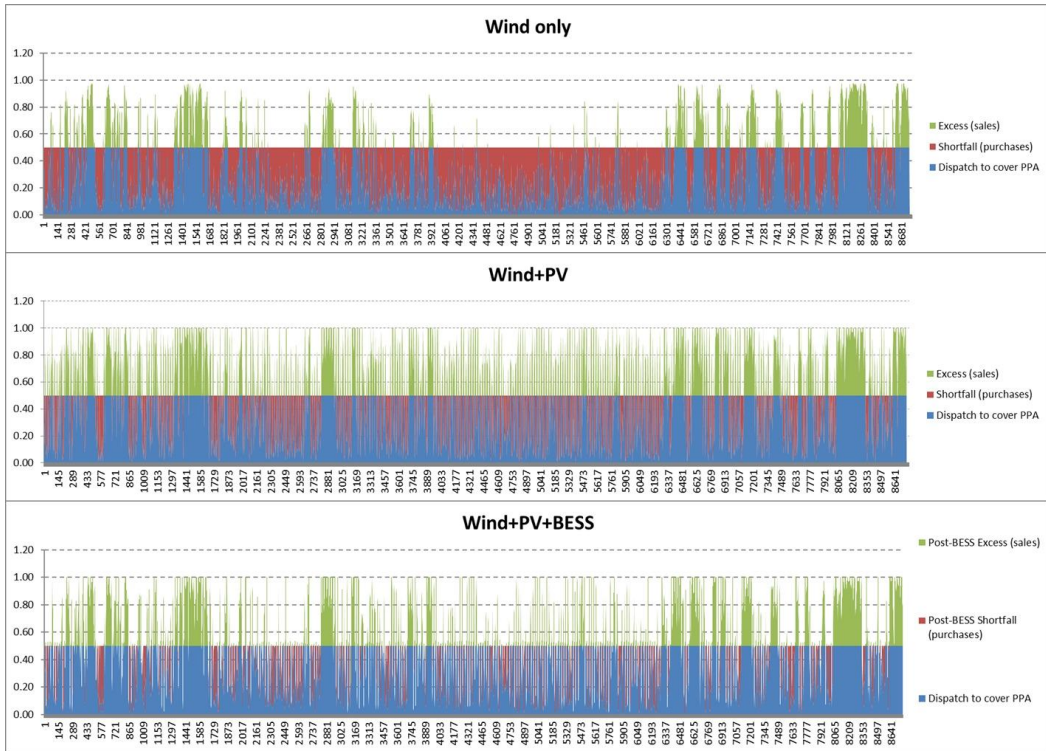
Source: K4K/EKON based on generation profiles from Renewables Ninja.







**Figure 3: Hourly generation results (first fortnight of the year)**  
 Source: K4K/EKON based on generation profiles from Renewables Ninja.



**Figure 4: Hourly generation results (all hours of the year)**  
 Source: K4K/EKON based on generation profiles from Renewables Ninja.