



## **Online-Appendix zu**

# **„The Effects of Battery Storage on Risk and Cost of Capital of Wind Park Investments“**

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## Appendix

### Appendix 1<sup>225</sup>

NPV = (Annuity Factor \* Yearly Cash Flow) – Initial Investment

$$\text{Annuity Factor: } \frac{1-(1+r)^{-n}}{r}$$

Where: n = number of years

r = WACC

Initial Investment = Battery Price in €/kWh \* Capacity

	Cash Flows in €												
	January	February	March	April	May	June	July	August	September	October	November	December	Sum
Standalone wind farm	359,164	278,575	226,293	140,750	143,375	116,060	117,112	103,213	152,950	169,359	265,903	385,330	2,458,083
with 25 MWh battery	381,649	302,349	260,470	166,792	161,531	132,704	131,311	117,958	176,719	196,091	291,410	411,533	2,730,517

10 years	<b>6.5 % WACC</b>		<u>WACC</u>	<u>Annuity Factor</u>	<u>Yearly return</u>	<u>Initial Investment</u>	<u>NPV</u>
	Standalone Windfarm	6.50%	7.188830223	2,458,083 €	- €	17,670,738 €	
	With battery 200 €/MWh	<b>3.53%</b>	8.302727129	2,730,517 €	5,000,000 €	17,670,738 €	
	With battery 160 €/MWh	<b>4.44%</b>	7.936496132	2,730,517 €	4,000,000 €	17,670,738 €	
10 years	<b>5.0 % WACC</b>		<u>WACC</u>	<u>Annuity Factor</u>	<u>Yearly return</u>	<u>Initial Investment</u>	<u>NPV</u>
	Standalone Windfarm	5.00%	7.721734929	2,458,083 €	- €	18,980,662 €	
	With battery 200 €/MWh	<b>2.43%</b>	8.782461821	2,730,517 €	5,000,000 €	18,980,662 €	
	With battery 160 €/MWh	<b>3.26%</b>	8.416230824	2,730,517 €	4,000,000 €	18,980,662 €	
10 years	<b>3.5 % WACC</b>		<u>WACC</u>	<u>Annuity Factor</u>	<u>Yearly return</u>	<u>Initial Investment</u>	<u>NPV</u>
	Standalone Windfarm	3.50%	8.316605323	2,458,083 €	- €	20,442,903 €	
	With battery 200 €/MWh	<b>1.31%</b>	9.317979634	2,730,517 €	5,000,000 €	20,442,903 €	
	With battery 160 €/MWh	<b>2.07%</b>	8.951748636	2,730,517 €	4,000,000 €	20,442,903 €	

<sup>225</sup> NPV calculation by using annuity factor based on Khatib (2014), p. 63.

		<u>WACC</u>	<u>Annuity Factor</u>	<u>Yearly return</u>	<u>Initial Investment</u>	<u>NPV</u>
<b>15 years</b>	<b>6.5 % WACC</b>					
	Standalone Windfarm	6.50%	9.402668855	2,458,083 €	- €	23,112,537 €
	With battery 200 €/MWh	<b>5.12%</b>	10.2956823	2,730,517 €	5,000,000 €	23,112,537 €
	With battery 160 €/MWh	<b>5.66%</b>	9.929451305	2,730,517 €	4,000,000 €	23,112,537 €
	<b>5.0 % WACC</b>					
	Standalone Windfarm	5.00%	10.37965804	2,458,083 €	- €	25,514,057 €
	With battery 200 €/MWh	<b>3.93%</b>	11.1751934	2,730,517 €	5,000,000 €	25,514,057 €
	With battery 160 €/MWh	<b>4.41%</b>	10.8089624	2,730,517 €	4,000,000 €	25,514,057 €
	<b>3.5 % WACC</b>					
Standalone Windfarm	3.50%	11.5174109	2,458,083 €	- €	28,310,747 €	
With battery 200 €/MWh	<b>2.70%</b>	12.19942815	2,730,517 €	5,000,000 €	28,310,747 €	
With battery 160 €/MWh	<b>3.12%</b>	11.83319715	2,730,517 €	4,000,000 €	28,310,747 €	

		<u>WACC</u>	<u>Annuity Factor</u>	<u>Yearly return</u>	<u>Initial Investment</u>	<u>NPV</u>
<b>20 years</b>	<b>6.5 % WACC</b>					
	Standalone Windfarm	6.50%	11.01850725	2,458,083 €	- €	27,084,401 €
	With battery 200 €/MWh	<b>5.70%</b>	11.7503021	2,730,517 €	5,000,000 €	27,084,401 €
	With battery 160 €/MWh	<b>6.09%</b>	11.3840711	2,730,517 €	4,000,000 €	27,084,401 €
	<b>5.0 % WACC</b>					
	Standalone Windfarm	5.00%	12.46221034	2,458,083 €	- €	30,633,142 €
	With battery 200 €/MWh	<b>4.46%</b>	13.04996121	2,730,517 €	5,000,000 €	30,633,142 €
	With battery 160 €/MWh	<b>4.79%</b>	12.68373021	2,730,517 €	4,000,000 €	30,633,142 €
	<b>3.5 % WACC</b>					
Standalone Windfarm	3.50%	14.2124033	2,458,083 €	- €	34,935,261 €	
With battery 200 €/MWh	<b>3.19%</b>	14.62553048	2,730,517 €	5,000,000 €	34,935,261 €	
With battery 160 €/MWh	<b>3.46%</b>	14.25929948	2,730,517 €	4,000,000 €	34,935,261 €	

*Appendix 1: Calculation of NPV and threshold WACC for 25 MWh configuration for a 10, 15 and 20 year timeframe<sup>226</sup>*

<sup>226</sup> The calculation was realized by using the annuity factor NPV calculation. To derive the same NPV as the standalone wind farm does, the calculation was solved for the WACC with a fixed NPV by using the Excel Solver. Mathematically, this means:

$$Yearly\ revenue_{VPP} * \frac{1 - (1 + WACC_{VPP})^{-n}}{WACC_{VPP}} - initial\ investment = Yearly\ revenue_{standalone\ farm} * \frac{1 - (1 + Reference\ WACC)^{-n}}{Reference\ WACC}$$

This equation then is solved for  $WACC_{VPP}$ .

## Appendix 2

Threshold battery price in €/kWh		WACC																	
		3.00%	3.25%	3.50%	3.75%	4.00%	4.25%	4.50%	4.75%	5.00%	5.25%	5.50%	5.75%	6.00%	6.25%	6.50%	6.75%	7.00%	
Capacity	timeframe																		
	20 years	168.6	164.8	161.1	157.5	154.0	150.7	147.4	144.3	141.3	138.3	135.5	132.7	130.0	127.4	124.9	122.4	120.1	
	15 years	135.3	132.9	130.5	128.3	126.0	123.8	121.7	119.7	117.6	115.7	113.8	111.9	110.1	108.3	106.6	104.9	103.2	
15 MWh	10 years	96.7	95.5	94.3	93.1	91.9	90.8	89.7	88.6	87.5	86.5	85.4	84.4	83.4	82.4	81.5	80.5	79.6	
	20 years	162.1	158.4	154.9	151.4	148.1	144.9	141.8	138.7	135.8	133.0	130.2	127.6	125.0	122.5	120.1	117.7	115.4	
	15 years	130.1	127.8	125.5	123.3	121.2	119.1	117.0	115.0	113.1	111.2	109.4	107.6	105.8	104.1	102.5	100.8	99.3	
25 MWh	10 years	93.0	91.8	90.6	89.5	88.4	87.3	86.2	85.2	84.1	83.1	82.1	81.2	80.2	79.3	78.3	77.4	76.5	
	20 years	147.0	143.6	140.4	137.3	134.3	131.3	128.5	125.8	123.1	120.6	118.1	115.7	113.3	111.1	108.9	106.7	104.7	
	15 years	117.9	115.8	113.8	111.8	109.8	108.0	106.1	104.3	102.5	100.8	99.2	97.5	96.0	94.4	92.9	91.4	90.0	
35 MWh	10 years	84.3	83.2	82.2	81.1	80.1	79.1	78.2	77.2	76.3	75.4	74.5	73.6	72.7	71.9	71.0	70.2	69.4	

Appendix 2: Numerical results of the critical battery price calculations<sup>227</sup>

<sup>227</sup> Calculations comparable to the calculations on the critical WACC in appendix 1. However, here is  $WACC_{VPP} = WACC_{standalone\ farm}$  and the NPV equation von appendix 1 was solved for the initial investment.