QUICK GUIDE – PARK WITH SCALER AND MESO SCALE WIND DATA CALIBRATED WITH TURBINE PRODUCTION

Purpose:

This quick guide shows you how to calculate expected Annual Energy Production (AEP) based on time series using EMD-WRF mesoscale data, calibrated with existing turbine production data.

PARK can calculate AEP with a plethora of input data and model configurations. In this guide, we will use hourly resolution EMD-WRF mesoscale modeled timeseries and utilize the embedded mesoscale terrain data. Third party mesoscale data can be used by treating the mesoscale data as "a mast" (see the other PARK quick guides)

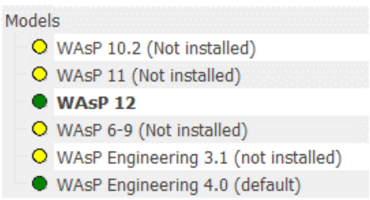
In this guide we assume you are familiar with the basic use of windPRO, like the creation of objects and how to import data into Meteo objects.

Outline of Guide:

1. **License and version requirements**
2. **Setup input data for PARK/MESO**
3. **Calibration of the SCALER**
4. **Calculation and results**

1. LICENSE AND VERSION REQUIREMENTS

WindPRO 4.1 with license to the module PARK and a subscription to EMD-WRF mesoscale data or purchase of WRF on-demand cluster credits. Also, a WAsP (11 or higher) license must be activated.



2. SETUP INPUT DATA FOR PARK/MESO

Establish the mesoscale wind data in Meteo objects. There are two ways:

A) **Based on EMD ERA5 EU+ or other pre-run (see list) mesoscale datasets**: Create a Meteo object, choose the "ON-Line" option, select the point to download, and choose period (recommended at least recent 20 years) – data will be downloaded. For more information, see the Meteorological Data Handling manual.

B) **Based on WRF on demand**: Run a WRF calculation on EMD cluster using the Mesoscale Data button in the Climate tab:

Once the data has been generated you will receive an email when it is ready. Then re-open the calculation and directly download the data. Meteo object(s) are automatically created. For more information see the EMD-WRF quick guide.

If not already established in the project:

- Insert the WTG objects to simulate.
- Establish roughness and elevation data and make a site data object linking these together.

3. CALIBRATION OF THE SCALER

Having turbines with production data close to the planned wind farm makes it possible to calibrate the mesoscale data to reproduce this production accurately – by turbine, in time, by direction, etc. The more detailed the reproduction, the more trustworthy the calibration.

There are several approaches depending on how detailed the available turbine production data is. This could be:

1. Annual production for an entire wind farm

Authors: Per Nielsen & Per Møller Nielsen (pmn@emd.dk)

2. Monthly production for each turbine
3. Monthly production and availability for each turbine
4. Detailed (10-min or hourly) production for each turbine

Ad. 1: Set up a calculation with annual aggregation. Use the result-to-file to take calculation results to Excel and compare the calculated values to the measured annual production. Adjust the Post calibration factor in SCALER until the PARK results match a ratio measured/calculated that reflects the expected loss (typically round 95%, but can vary much by project).

Ad. 2 & 3: Here, the PERFORMANCE CHECK module is used. A first step can be to make a wind index correction within this module to establish a long term expected production for each turbine. Then, save these values in existing turbine objects on "statistic" tab. After, the calculation report will show the "Goodness" for each turbine in the PARK report. Adjust the Post calibration factor in SCALER until all turbines come up with goodness around 100% (assuming the long term expected production figures are at 100% availability and before grid loss deduction). If the goodness varies much turbine by turbine, there will be a need to look for reasons, e.g., the wake model settings, power curves etc. Another next step can be to compare calculated production with measured production in PERFORMANCE CHECK at different aggregation levels. Here, different filters can be applied.

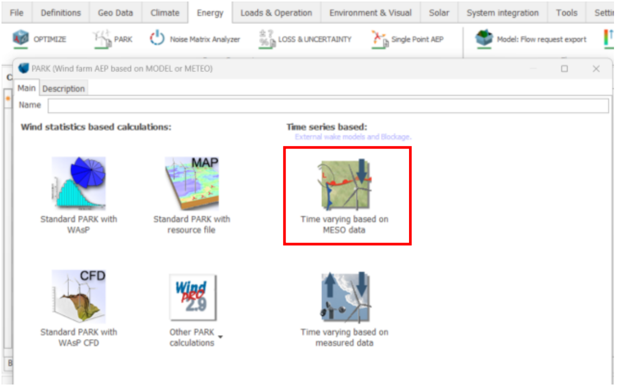
Ad 4: Here, the PERFORMANCE CHECK module is required since it has all the features for comparing on a detailed time step basis. Aggregation by, e.g., direction, can explain a lot about wake model settings or inefficient roughness description. This is where it is possible to make a very accurate model calculation setup.

Here is illustrated the "simplest" approach (see PERFORMANCE CHECK manual for the more refined options).

In this example calculation, we use an existing wind farm "Black Hill". The actual production data can be found at the British REF:

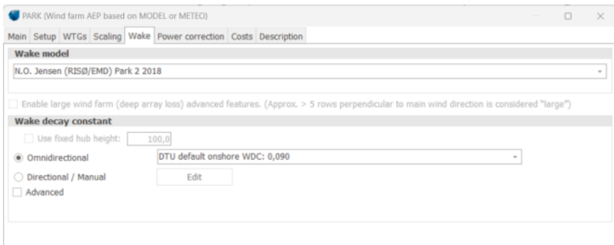
http://www.ref.org.uk/generators/index.php

The data is annual production (AEP) for the full wind farm with 22x 1300 kW turbines with 60m rotor diameter and 47m hub height. The AEP periods are 1. April to 31.March with 8 full years (2007-15) available.

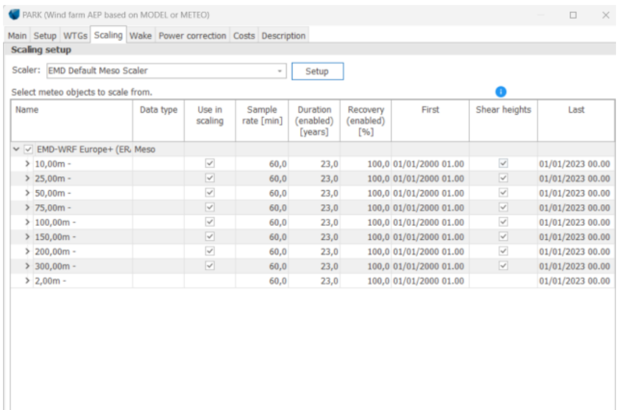


Click the upper right button to choose a timeseries based mesoscale data calculation.

Go to the "WTGs" tab and select the turbines to include in the calculation.



Next, in the "Scaling" tab, choose the "EMD Default Meso Scaler" and select the EMD-WRF dataset in the list:



In the bottom, choose to calculate from 1.4.2007, since this is where our first complete year with production data starts (see later).

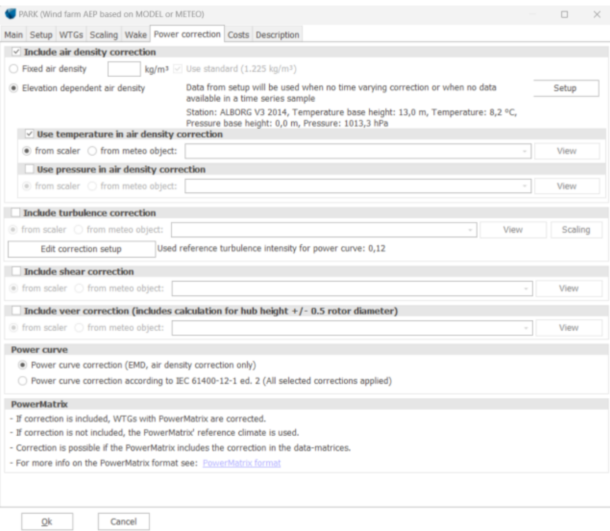
The SCALER will downscale the mesoscale data based on the mesoscale terrain in the Meteo object AND the Micro terrain + model selected in the SCALER setup.

This will transfer the Meso data to each turbine position for each hour.

In the **Wake** tab**,** it is not as much the wake model that decides the accuracy of the wake loss calculation as the parameters that are used. For this model, the Wake Decay Constant (WDC) decides the results. The WDC shall, basically, be chosen based on the turbulence, if this is available. If not, different terrain types are described that, in combination with hub height, give reasonable choices.

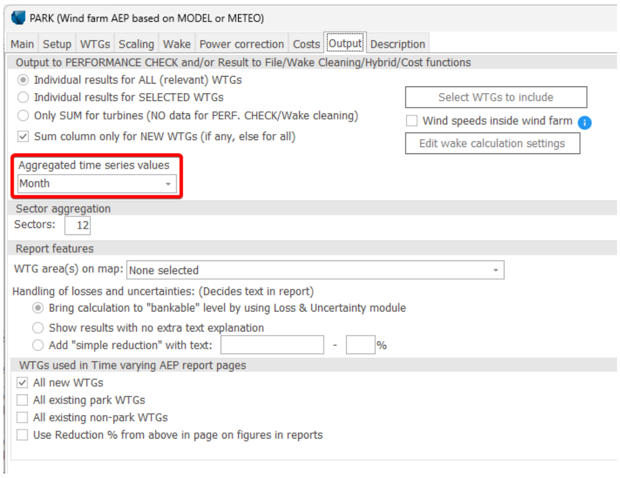
Here, with Hub height 47m, the logical choice will be "HH 50m, Very open farmland, WDC 0.062".

Next, go to the Power Correction tab:



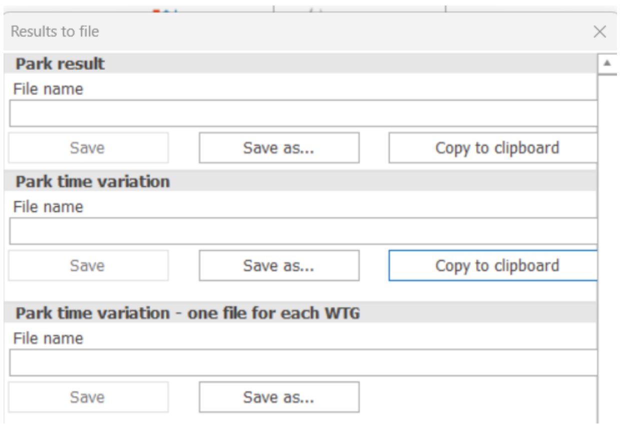
The recommendation here is only to check the Temperature correction, since this gives a more precise month by month calculation. The other corrections are more for "experimental use", these do not, in general, affect the AEP result significantly, although at "special sites" with, e.g. extreme shear, there might be some effect.

Lastly, go to the Output tab:



Note especially the "Aggregation" options. This is, by default, Month, partly to save memory. But, if you need the hourly values (for use in PERFORMANCE CHECK or for some detailed calculations in LOSS & UNCERTAINTY), this must be changed to "none". In this case, we use "Month", even though the data is available in years, but only from April to March. Therefore, aggregation by calendar year will not be useful to compare to informed production values.

Now click Ok to run the calculation. Once done, right click on calculation and choose "Result to file" and copy to clipboard the "Park time variation":



Insert in Excel:

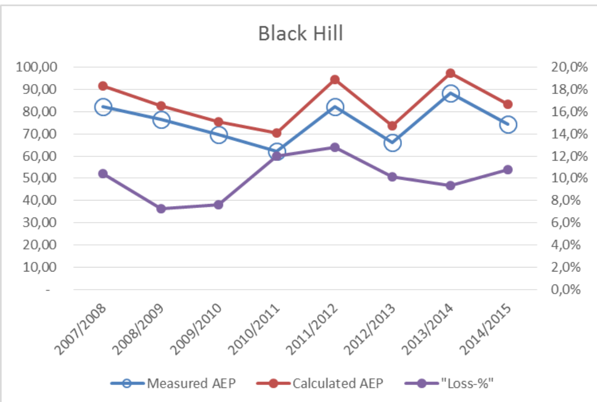
		SIMPLE Meso scal	Scaler:	EMD Def	Meteo dat	EmdConwx_
		01-05-2016 13:56	Total		For reference WTG: [1]	
		Time stamp	Power	Time	Free wind	Reduced w
Period	Month. Prod.	Date-time	[kW]	[h]	[m/s]	[m/s]
1	5839128	01-04-2007 00:00	8109,9	720	7,1	6,9
1	6065609	~~01-05-2007 00:00~~	8152,7	744	7,2	7,1
1	2861784	01-06-2007 00:00	3974,7	720	5	4,8
1	5318335	01-07-2007 00:00	7148,3	744	6,7	6,6
1	6451298	01-08-2007 00:00	8671,1	744	7,3	7,2
1	8126352	01-09-2007 00:00	11286,6	720	8,3	8,2
1	5400473	01-10-2007 00:00	7258,7	744	7	7
1	9696384	01-11-2007 00:00	13467,2	720	9	8,9
1	9350071	01-12-2007 00:00	12567,3	744	8,9	8,8
1	10852133	01-01-2008 00:00	14586,2	744	10,3	10,1
1	10127009	01-02-2008 00:00	14550,3	696	10	10
1	11636904	01-03-2008 00:00	15641	744	10,1	10
2	5441328	01-04-2008 00:00	7557,4	720	6,8	6,5
2	2891779	01-05-2008 00:00	3886,8	744	5,6	5,2

Here you see the average power in each month for all turbines. By multiplying the power with the number of hours in each month you get the calculated monthly production.

You can then proceed to create a new (pivot) table to compare the calculated production with the measured production:

Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	91,73	9,57	10,4%
2008/2009	76,69	82,66	5,98	7,2%
2009/2010	69,57	75,29	5,72	7,6%
2010/2011	62,08	70,57	8,50	12,0%
2011/2012	82,33	94,37	12,04	12,8%
2012/2013	66,30	73,79	7,48	10,1%
2013/2014	88,24	97,35	9,11	9,4%
2014/2015	74,53	83,54	9,02	10,8%
Average:	75,24	83,66	8,43	10,1%

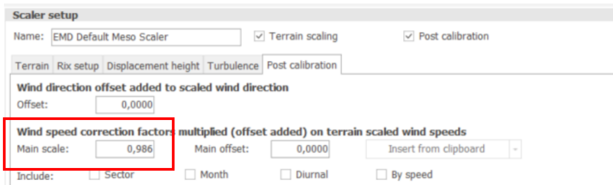
Now, we have the period productions as measured and calculated, and the differences are calculated, also, as "Loss-%".



A graphic presentation makes the picture clearer. It is obvious that the mesoscale based calculation catch the annual variations well, but there seems to be an over prediction. Notice, that the calculated production does not include any losses beside wake, while the measured production has losses built into the data.

A 10% loss for the 8-year period seems high. Looking at individual years, it is a minimum of 7.2%. Is this realistic? It could be. It depends on which losses occurred, how well the wind farm had been operated, etc. In this case, we are informed that, in the "better years", only a 5% loss should be observed. Therefore, we now calibrate our scaler to reach round 5% loss from 2008-10. We, thereby, have to get the AEP calculation down by around 2%.

From the export results of the PARK calculation, we can see the "Sensitivity = ratio between windspeed and power" is calculated to 1.7. In order to bring down the AEP by 2.4% (to get the average 5% loss for 2008-10), we shall scale the wind speed by 2.4/1.7 = 1.4. We reopen the calculation and enter a scaling factor of 0.986 (reduced 1.4%):



Then recalculate and paste the new results, and the table is updated:

Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	89,48	7,33	8,2%
2008/2009	76,69	80,39	3,70	4,6%
2009/2010	69,57	73,03	3,46	4,7%
2010/2011	62,08	68,44	6,37	9,3%
2011/2012	82,33	92,23	9,90	10,7%
2012/2013	66,30	71,64	5,34	7,4%
2013/2014	88,24	94,87	6,63	7,0%
2014/2015	74,53	81,54	7,02	8,6%
Average:	75,24	81,45	6,22	7,6%

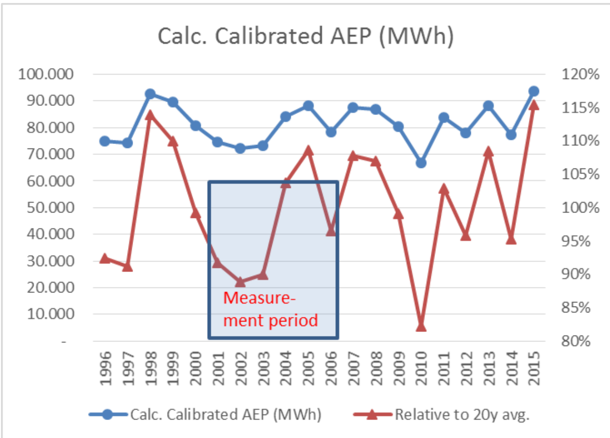
We do not hit exact 5% in average for 2008-10 due to non-linearity, and might, therefore, change the factor 0.986 to 0.988 to get exact what is wanted. Here, we accept the results as okay – to make it better we must contact the wind farm management for more detailed information.

4. CALCULATIONS AND RESULTS

As the calculation setup is now ready, the only modification for a long-term expectation would be to set the period to 20 years.

Here the calculation is setup for 1996-2015.

The aggregation is changed to Year under setup tab, and the results are:



The time step based calculation offers, as seen, the benefit of illustrating the annual variations based on historical data - how much can be expected in variations year by year. It is also illustrated here how the wind conditions were during measurements on the site (clearly below long term average).

		MWh/y	
Calc. last 20y		81,32	
First 10		80,48	99,0%
Last 10		82,16	101,0%

And, as support for using 10 or 20 years as the long term reference period, the table above is informative. In this case, using only the last 10 years would give 1% higher calculated AEP.

To finalize the AEP study, a loss and uncertainty evaluation must be performed. Due to the coarse nature of the production data, the uncertainty will be higher than if more detailled data had been available.

It will be difficult to judge the uncertainty, but it is defenitely lower with this calculation concept than based on the traditional wind statistic concept - partly since weibull fit problems are handled better and partly since it gives much more confidence in being able to evaluate the model results against measurements in time instead of just having one average value to calculate with.

It should be noted that the calibration process illustrated here does not provide a refined model calibration – all is put into scaling the meso scaled wind speed. Other issues, like the wake loss model settings, are not possible to fine tune when only sum production for all turbines is available (see other PARK guides where the same project is recalculated using local measurements, which gives a better feedback for model calibration.

It is especially important to calibrate the right parts in the model of a new project when very different turbines and hub heights will be calculated.