WindSim 12

WindSim 12 changes

- Terrain
  - Geometrical and Arithmetical Grid Expansion
- Wind Fields
  - New "HYPRE" Solver and New PHOENICS Version
  - New Boundary Condition at the Top (Diffusive Link)
  - Simplified Values for Convergency
  - Reduced Wind Database Horizontally
- Objects
  - Power Curve Header Information about IEC Turbine Class
- Wind Resources
  - Export of Wind Resource Maps to Surfer Format ".GRD"
- Energy
  - AEP and IEC Report Exports
  - Matrix Table Export
  - Change in the Time Series AEP Normalization
- Meso Micro Coupling

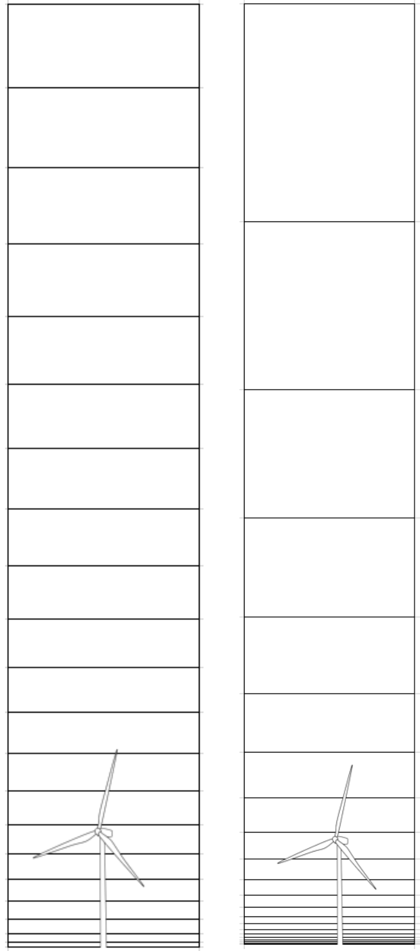
Terrain | Geometric expansion

- Arithmetical grid expansion:
  - Traditional method of grid expansion.
  - Grid expands at a uniform rate.
  - Number of cells in the grid increases by a constant factor in each expansion step.

- Geometrical grid expansion:
  - Allows faster expansion in the vertical direction compared to the Arithmetical method.
  - Cell height in the grid increases exponentially with each expansion step.
  - Results in a denser resolution in the lower part of the grid.
  - Uses fewer cells overall.

Properties

1: Terrain extension	
Coordinate system	Global
X-range	**318000; 332975**
Y-range	**7180000; 7194975**
Projection	**_UTM _WGS_84 33**
2: Roughness	
Roughness height	Read from grid.gws
3: Numerical model	
Automatic gridding	False
Refinement type	Refinement area
Refinement area, X-range	**322991; 327984**
Refinement area, Y-range	**7184991; 7189984**
Height above terrain	Automatic
Horizontal gridding	Maximum number of cells
Maximum number of cells	10000000
Ratio additive length to resoluti	0.5
Vertical expansion	Geometrical
Height distribution factor	0.3
Number of cells in Z direction	21
First vertical cell height	2
4: Smoothing	
Smoothing type	No smoothing
5: Forest	
Forest	Disregard forest



Terrain | First vertical cell height

- First vertical cell height in WindSim:
  - Determines the starting point for wind flow simulation.
  - Default value in WindSim is 2m.
  - Balances accuracy and computational efficiency.

- Importance of choosing the appropriate first vertical cell height:
  - Affects resolution of wind flow characteristics at different heights.
  - Higher height leads to coarser resolution, while lower height increases computational time and complexity.

- Adjusting the first vertical cell height:
  - Terrain and weather conditions of the site should be considered.
  - Complex terrain or vegetation may require a lower first vertical cell height for accurate results.
  - Relatively flat and uniform sites may use a higher first vertical cell height.

WindFields | New PHOENICS version which includes “HYPRE”

- New solver setup in WindSim:
  - Enabled by integration of the HYPRE library.
  - Features the BoomerAMG preconditioner and solver.
  - Utilizes algebraic multigrid (AMG) algorithm for linear equation solver in GCV algorithm.

- Benefits of the new solver setup:
  - Improved convergence behavior for large models with parallel option.
  - Enables future development possibilities, such as solving on semi-unstructured grids.

- Availability:
  - New solver setup available with the latest version of Phoenics.

- Integration of HYPRE library:
  - Supports high-performance computations and accurate simulation results.

WindFields | New PHOENICS version which includes "HYPRE"

windsim

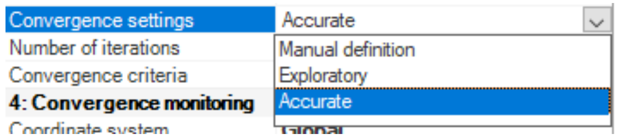
- Challenge in Computational Fluid Dynamics (CFD):
  - Dealing with a large number of linked equations.
  - Equations describe fluid behavior at each cell in the grid.
  - Millions of cells need simultaneous equation solving.
- Benefits of Multigrid Solver:
  - Efficiently homes in on the right solution.
  - Faster convergence compared to solving only on the fine grid.
- Steps of Multigrid Solver:
  - Start Small:
    - Solve the problem on the fine, detailed grid with a few steps.
    - Initial solution is not perfect but provides a good starting point.
  - Go Big:
    - Create a coarser, simpler grid.
    - Problem appears easier on the coarser grid.
    - Solver refines the solution on this grid.
  - Get Detailed Again:
    - Take the solution from the coarser grid.
    - Use it as a starting point to solve the problem again on the fine grid.

T

WindFields | New boundary condition at the top (Diffusive link)

- Diffusive link boundary condition:
  - New option in WindSim for controlling flow of air.
  - Sets fixed pressure at the top of the model and imposes a constant speed.
- Benefits of Diffusive link boundary condition:
  - Enables lowering of model height and using fewer cells vertically.
  - Optimizes computational resources and improves efficiency.
- Relevance for offshore applications:
  - Particularly useful for offshore simulations.
  - Helps optimize computational resources in offshore modeling scenarios.

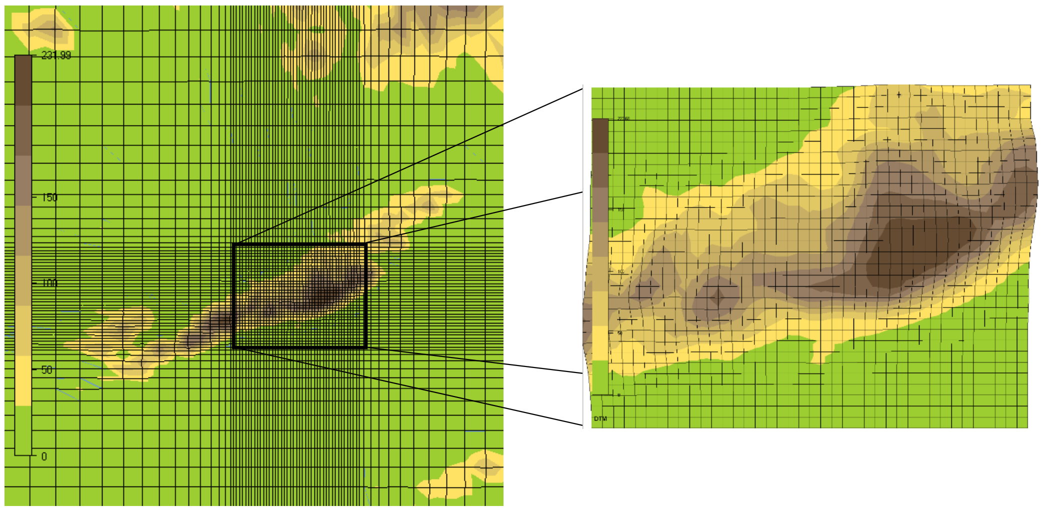
WindFields | Simplified values for convergency



- Options for determining convergence level:
  - Exploratory (0.005):
    - Rapid evaluation of simulation scenarios with lower accuracy.
    - Useful for screening and initial analysis.
    - Recommended for exploratory or preliminary analysis.
  - Accurate (0.0005) default:
    - Designed for high accuracy simulation results.
    - Longer simulation times.
    - Suitable for critical simulation applications where accuracy is paramount.
    - Results are trustworthy and reliable.
    - Recommended as the default for most simulation scenarios, especially when accuracy is critical and time is not a constraint.
- Manual:
  - Users can override the default settings and define their own convergence level.

WindFields | Reduced wind database horizontally

- XY reduced wind database option:
  - Allows performing modules only on the internal part of the horizontal grid.
  - Applicable when a refinement type (Refinement area, Refinement file, or Actuator Disc) is defined.
  - Enhances simulation speed and efficiency.
  - Maintains a uniform grid inside the refined area.
- Activation and functionality:
  - Option activated in WindFields.
  - Complete wind simulation performed on the entire grid.
  - Subsequent calculations run only on the internal part, where points of interest are typically located.



Objects | Power curve header information about IEC turbine class

windsim

- The power curve header has been enhanced to include IEC turbine class information

Class AI

```
WindSim version     : 500
turbin manufacturer: Vestas
type specification : V90 mode0 hub height 80m
IEC class letter    : A
IEC class number    : I
max effect          : 2000
air density         : 1.225
Cut-in speed        : 4
Cut-out speed       : 25
Rated wind speed    : 13
```

Class CII

```
WindSim version     : 500
turbin manufacturer: Vestas
type specification : V90 mode0 hub height 80m
IEC class letter    : C
IEC class number    : II
max effect          : 2000
air density         : 1.225
Cut-in speed        : 4
Cut-out speed       : 25
Rated wind speed    : 13
```

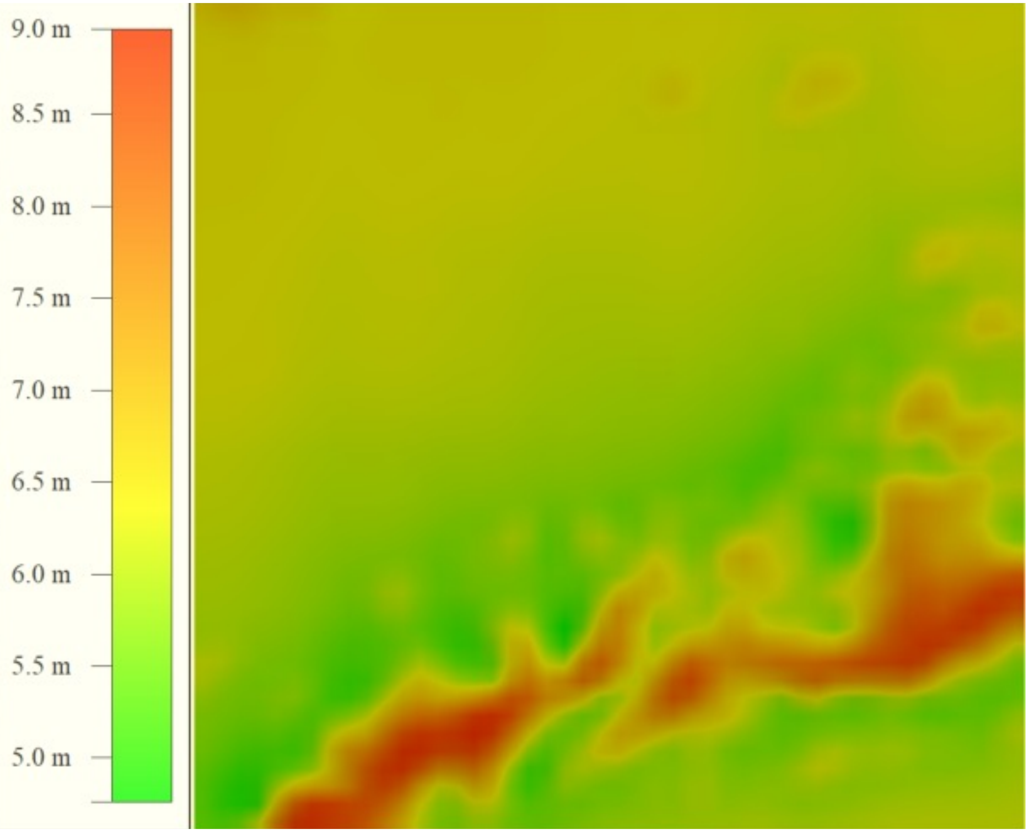
Special class S and manufacturer's defined Vref and Iref.

```
WindSim version     : 500
turbin manufacturer: Vestas
type specification : V90 mode0 hub height 80m
IEC class letter    : S
IEC Vref            : 32.5
IEC Iref            : 0.13
max effect          : 2000
air density         : 1.225
Cut-in speed        : 4
Cut-out speed       : 25
Rated wind speed    : 13
```

Figure 6: Examples of .pws headers with IEC information included.

Wind Resources | Export of wind resource maps to Surfer format ".grd"

- New export feature for wind resource maps:
  - Generates a .grd file containing grid information and variable values at each node.
  - Facilitates data import and visualization.
- Location of exported files:
  - Files located in the "project\layout\energy\grd" and "project\windfield\grd" directories.
  - Link to the exported files provided in the report.
- Benefits of the export feature:
  - Compatibility with various software tools.
  - Users can work with wind resource maps in their preferred software.
  - Enhances convenience and accessibility of data sharing and analysis.



Energy | AEP and IEC report exports

windsim

- The AEP and IEC results are tab-separated text files that provide data on Annual energy production and turbine class suitability according to IEC 61400-1 ed. 4 (2019) standards.

- AEP Results file:
  - Provides information on the annual energy production of a wind farm.
  - Includes data such as average wind speed, Weibull parameters, energy and waked energy, extreme wind (50-years), shear exponent, inflow angle, and information about the nearest turbines.

```
Total wind farm production without wake effect:                 131258.0 MWh/year
Total wind farm production contemplating wake effects:                 131258.0 MWh/year
Mean speed at the reference point:                 8.06 m/s
```

Wind turbine type	Label	X (m)	Y (m)	Z (m)	H (m)	A Weibull (m/s)	k Weibull (-)	Power density (W/mï¿½)	Annual Energy Production (MWh/year)	Mean speed (m/s)	Mean REWS (m/s				
	Hundhammer_83m	326703.81	7185926.00	163.84	83.00	8.820	1.680	698.640	-	8.060	-	-	-	-	-
V90 mode0 hub height 80m	wecs1	325869.00	7185782.00	154.01	80.00	8.980	1.730	697.510	7698.00	8.060	-	76			
V90 mode0 hub height 80m	wecs2	326031.00	7185924.00	163.93	80.00	8.870	1.670	716.500	7816.50	8.150	-	78			
V90 mode0 hub height 80m	wecs3	326230.00	7186122.00	128.66	80.00	8.000	1.650	530.220	6823.40	7.370	-	68			
V90 mode0 hub height 80m	wecs4	326564.00	7185983.00	152.75	80.00	8.600	1.730	614.180	7327.90	7.740	-	73			
V90 mode0 hub height 80m	wecs5	326803.00	7185965.00	167.85	80.00	8.850	1.710	677.870	7631.00	7.980	-	76			
V90 mode0 hub height 80m	wecs6	327057.00	7185983.00	183.19	80.00	8.810	1.620	727.080	7822.40	8.160	-	78			
V90 mode0 hub height 80m	wecs7	327305.00	7185982.00	191.85	80.00	9.230	1.710	776.620	7917.30	8.300	-	79			
V90 mode0 hub height 80m	wecs8	327505.00	7186159.00	218.06	80.00	9.290	1.630	844.310	8259.40	8.570	-	82			
V90 mode0 hub height 80m	wecs9	327705.00	7186322.00	221.30	80.00	9.440	1.670	856.820	8302.60	8.620	-	83			
V90 mode0 hub height 80m	wecs10	327932.00	7186491.00	196.89	80.00	9.220	1.710	768.290	7990.00	8.320	-	79			
V90 mode0 hub height 80m	wecs11	328232.00	7186583.00	175.45	80.00	9.190	1.700	762.550	7955.60	8.280	-	79			
V90 mode0 hub height 80m	wecs12	328387.00	7186747.00	175.51	80.00	9.210	1.720	775.410	7986.60	8.320	-	79			
V90 mode0 hub height 80m	wecs13	328659.00	7186834.00	162.49	80.00	8.980	1.680	730.820	7876.00	8.200	-	78			
V90 mode0 hub height 80m	wecs14	328833.00	7186977.00	127.28	80.00	8.570	1.680	647.260	7468.60	7.860	-	74			
V90 mode0 hub height 80m	wecs15	327171.00	7186249.00	195.62	80.00	8.780	1.670	693.810	7577.30	8.000	-	75			
V90 mode0 hub height 80m	wecs16	327391.00	7186440.00	206.96	80.00	8.720	1.590	738.400	7692.90	8.130	-	76			
V90 mode0 hub height 80m	wecs17	327336.00	7186641.00	176.08	80.00	8.400	1.600	644.930	7112.50	7.710	-	71			

Energy | AEP and IEC report exports

- IEC Results file:
  - Contains data related to turbine class suitability analysis based on IEC 61400-1 ed. 4 (2019) standards.
  - Includes information about the turbine class and related Iref and Vref values.
  - Provides data on extreme wind (50-years), Weibull parameters, wind distribution analysis results, mean effective turbulence intensity, turbulence analysis results, IEC inflow angle analysis results, shear exponent minimum and maximum, and extreme turbulence analysis results.

	X (m)	Y (m)	Z (m)	H (m)	Class	IEC Iref	Wohler Exponent	Reference mast for the IEC turbulence computations	IEC Vref	Extreme mean wind speed (50-year)(m/s)	A Weibull (m/s)	k Weibull (-)	Wind distr					
wecs1	325869.00	7185782.00	154.01	80.00	NOdef	0.16	10	All	42.50	37.1	8.980	1.730	True	0.402	FALSE	4.086	6.911	180.000
wecs2	326031.00	7185924.00	163.93	80.00	NOdef	0.16	10	All	42.50	38.5	8.870	1.670	True	0.390	FALSE	2.569	4.333	120.000
wecs3	326230.00	7186122.00	128.66	80.00	NOdef	0.16	10	All	42.50	30.9	8.000	1.650	True	0.414	FALSE	3.521	5.749	0.000
wecs4	326564.00	7185983.00	152.75	80.00	NOdef	0.16	10	All	42.50	33.1	8.600	1.730	True	0.416	FALSE	1.847	3.370	210.000
wecs5	326803.00	7185965.00	167.85	80.00	NOdef	0.16	10	All	42.50	39.6	8.850	1.710	True	0.424	FALSE	2.970	5.822	180.000
wecs6	327057.00	7185983.00	183.19	80.00	NOdef	0.16	10	All	42.50	39.6	8.810	1.620	True	0.422	FALSE	3.892	7.461	180.000
wecs7	327305.00	7185982.00	191.85	80.00	NOdef	0.16	10	All	42.50	38.3	9.230	1.710	FALSE	0.410	FALSE	7.180	11.663	180.000
wecs8	327505.00	7186159.00	218.06	80.00	NOdef	0.16	10	All	42.50	40.3	9.290	1.630	FALSE	0.384	FALSE	4.316	6.753	150.000
wecs9	327705.00	7186322.00	221.30	80.00	NOdef	0.16	10	All	42.50	40.7	9.440	1.670	FALSE	0.367	FALSE	2.216	3.894	120.000
wecs10	327932.00	7186491.00	196.89	80.00	NOdef	0.16	10	All	42.50	41.0	9.220	1.710	FALSE	0.383	FALSE	2.662	5.624	60.000
wecs11	328232.00	7186583.00	175.45	80.00	NOdef	0.16	10	All	42.50	41.5	9.190	1.700	FALSE	0.401	FALSE	2.367	4.279	150.000
wecs12	328387.00	7186747.00	175.51	80.00	NOdef	0.16	10	All	42.50	38.7	9.210	1.720	FALSE	0.379	FALSE	2.539	3.958	120.000
wecs13	328659.00	7186834.00	162.49	80.00	NOdef	0.16	10	All	42.50	38.3	8.980	1.680	True	0.381	FALSE	2.465	3.653	120.000
wecs14	328833.00	7186977.00	127.28	80.00	NOdef	0.16	10	All	42.50	36.9	8.570	1.680	True	0.395	FALSE	4.487	9.561	60.000
wecs15	327171.00	7186249.00	195.62	80.00	NOdef	0.16	10	All	42.50	33.5	8.780	1.670	True	0.395	FALSE	5.618	8.614	300.000
wecs16	327391.00	7186440.00	206.96	80.00	NOdef	0.16	10	All	42.50	32.9	8.720	1.590	True	0.416	FALSE	2.924	4.909	330.000
wecs17	327336.00	7186641.00	176.08	80.00	NOdef	0.16	10	All	42.50	34.2	8.400	1.600	True	0.413	FALSE	3.733	5.707	330.000

Energy | Matrix table export

- The Matrix table export is a tab-separated file that provides a sector-wise breakdown of turbine energy production, energy including wake, turbulence, and speed frequencies.
- The turbulence matrix includes data on Ambient and Effective turbulence and their extrapolation when observed data is missing.
- This allows for the analysis of specific cases such as:
  - directional curtailment
  - sector management systems
  - IEC analysis checks
  - and more.
- The tab-separated format makes it easy to import the data into other software for further processing.

Ambient turbulence information
Mean takes into account the directional frequency of the bin speed

Dir	0.0	30.0	60.0	90.0	120.0	150.0	180.0	210.0	240.0
1.5	1.474	0.817	0.836	1.001	1.188	1.131	1.260	1.466	1.603
2.5	0.803	0.231	0.377	0.422	0.561	0.509	0.582	0.774	0.920
3.5	0.517	0.105	0.301	0.262	0.378	0.366	0.399	0.508	0.584
4.5	0.400	0.088	0.188	0.182	0.255	0.255	0.314	0.354	0.434
5.5	0.397	0.070	0.149	0.169	0.189	0.194	0.251	0.281	0.371
6.5	0.320	0.062	0.112	0.157	0.161	0.169	0.214	0.239	0.301
7.5	0.282	0.052	0.090	0.125	0.141	0.148	0.182	0.206	0.261
8.5	0.227	0.055	0.050	0.110	0.118	0.134	0.158	0.193	0.225
9.5	0.193	0.033	0.062	0.091	0.105	0.126	0.141	0.155	0.200
10.5	0.261	0.014	0.065	0.086	0.099	0.112	0.127	0.145	0.177
11.5	0.222	0.183	0.050	0.071	0.090	0.105	0.119	0.136	0.174
12.5	0.185	0.023	0.036	0.075	0.088	0.095	0.107	0.122	0.156
13.5	0.167	0.032	0.027	0.094	0.084	0.091	0.097	0.120	0.139
14.5	0.139	0.019	0.009	0.097	0.081	0.076	0.093	0.119	0.129
15.5	0.195	-	0.020	0.122	0.077	0.073	0.079	0.120	0.122
16.5	0.239	-	-	0.084	0.066	0.074	0.086	0.108	0.117
17.5	0.166	-	-	0.057	0.062	0.067	0.072	0.107	0.106
18.5	0.229	-	-	0.038	0.059	0.070	0.064	0.081	0.104
19.5	0.088	-	-	0.021	0.058	0.065	0.059	0.088	0.102
20.5	0.019	-	-	-	0.062	0.054	0.021	0.079	0.101
21.5	0.112	-	-	-	0.053	0.038	0.012	0.070	0.083
22.5	0.108	-	-	-	0.051	0.050	-	0.074	0.094
23.5	0.195	-	-	-	0.045	0.042	-	0.055	0.084
24.5	-	-	-	-	0.037	0.044	-	0.056	0.070
25.5	-	-	-	-	0.034	0.031	-	0.046	0.071
26.5	-	-	-	-	0.032	0.045	-	0.021	0.060
27.5	-	-	-	-	0.011	0.012	-	0.045	0.043
28.5	-	-	-	-	-	0.026	-	0.010	0.055
29.5	-	-	-	-	0.012	0.013	-	-	0.076
30.5	-	-	-	-	-	0.011	-	-	0.066

Energy | Change in the time series AEP normalization

- Traditional calculation methods in WindSim:
  - Utilize wind rose representation of climatology.
  - Converted and transferred to turbine positions.
  - Inaccuracies due to interpolation of wind speed frequencies, especially with significant directional shifts.
  - Minor impact, but can reach several percent in strongly guided climates.
- WindSim 11 approach:
  - Direct transfer of measurement time series to turbine positions.
  - Avoids conversion to wind rose.
  - Calculates turbine power output based on instantaneous wind speed.
  - Assumed zero power output in the absence of measurements.
- WindSim 12 feature:
  - Retains direct transfer of measurement time series.
  - Changes normalization of Annual Energy Production (AEP).
  - Disregards data gaps and averages power output only over measurement instances.
  - Results in relatively higher AEP values that align more with other methods in the report.

Meso Micro Coupling

- The User Interface of the software has undergone several improvements, including the addition of a postprocessing feature for Self-Organizing Map (SOM) cases.

- The Wind Resource and Energy module now incorporates SOM results by weighting frequency-based sectors, as typically used in WindSim.

- Please note that the postprocessing feature is currently in beta testing, as some energy export and IEC calculation functionality is not yet available. For more information, please refer to the guide "GettingStarted_Meso-microscale_coupling.pdf".

- More on MMC later today by Juho

WindSim Virtual Desktop

windsim

- Azure Virtual Machine
    - Windows 11
    - WindSim installed
    - In same datacenter as Accelerator
        - Very high bandwidth network connection
    - No need to have anything installed in your own network

vm-wvd-CompanyName.rdp