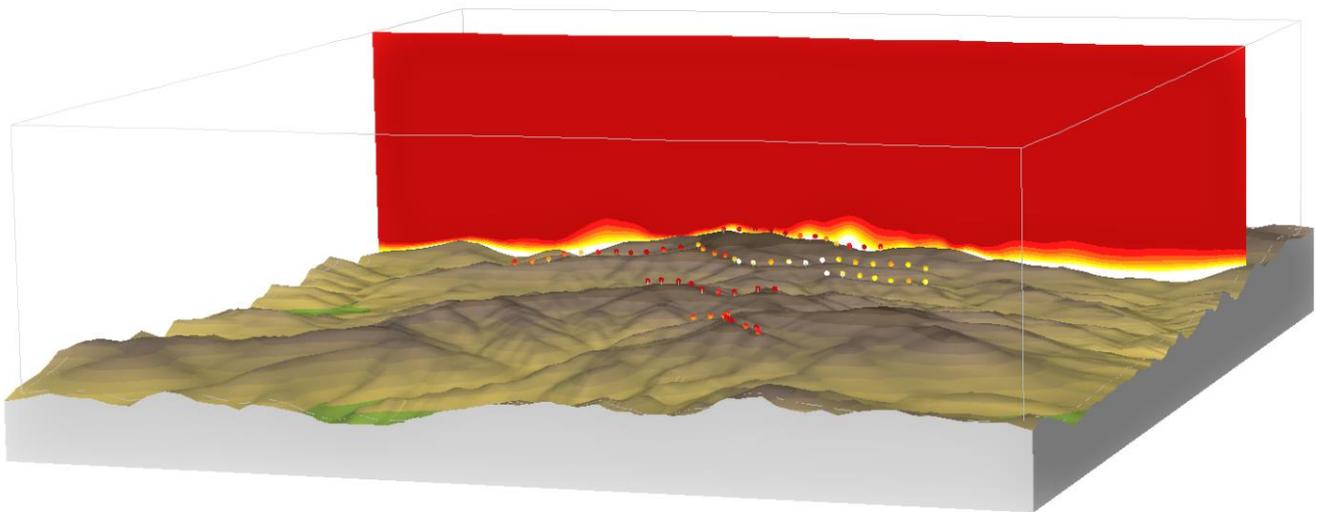# Wind Farm Design
CHAMPIONSHIP

Maximize energy production

Find the windiest position for each wind turbine

REVISION HISTORY

Version	date	summary
1.0	15/08/2018	Original issue
1.1	30/08/2018	Replacement of figure 3
1.2	12/10/2018	Introduce a new rule on project specific input with associated corrections and extensions of the text

windsim

Wind Farm Design CHAMPIONSHIP

You are hereby invited to take part in the wind farm design championship. The target is to design the world's best performing wind farm, that is the wind farm with the highest energy production. But, this is not a championship in finding the windiest spot in the world. This is a championship in designing wind farms, finding the best layout for your particular site. We need to define some rules, and we need to find some suitable wind farm design software. Let's look at the software first.

WindSim and WindSim Express
We will use WindSim and its companion WindSim Express, which can be downloaded from http://windsim.com/download/latest-version.aspx. (Notice that a hardware key with a valid license is required to run WindSim) WindSim is a so-called "Wind Farm Design Software" which will guide you through the following design steps:

1) Establish a 3D numerical model of the wind farm area, based on elevation and land cover data
2) Simulate the local wind fields
3) Establish information about the local wind climate, we call it a climatology
4) Establish the wind resource map
5) Positioning the turbines at optimal spots, maximize the energy based on the wind resource map and wake losses

Here is a short guidance on which software and modules to use to perform the above steps. We assume you already have basic knowledge on how to operate WindSim. If you are a new user we recommend you to visit the link "Learning WindSim": http://windsim.com/library/learning-windsim.aspx

3D numerical model
It is recommended to use WindSim Express to establish the 3D numerical model. WindSim Express is designed as a wizard which will extract terrain elevation and land cover data from online global datasets, you will be able to establish 3D numerical models all over the world within seconds.

Land cover is the physical material at the surface of the earth. Land covers include grass, trees, bare ground, water, cities etc. Depending on the land cover the wind will be slowed down more or less. In wind energy it is convenient to replace the land cover type with a roughness height which is a measure of the friction towards the ground. The higher the roughness height is, the higher is the friction and the lower is the wind speed. The replacement of land cover types with roughness heights is done automatically in WindSim Express.

Towards the final setup of the 3D numerical model it is recommended to swap from WindSim Express to WindSim, as WindSim allows for larger flexibility in the setup. But, also because we will use WindSim for all the remaining steps. In WindSim Express right after the 3D model has been displayed you should click the lower left button "Switch to WindSim". In the WindSim module "*Terrain*" you make your final decision on model extensions and resolution. Now you have established a 3D numerical model, you are ready to perform the wind simulations.

Simulations
Simulations of the local wind fields are done in WindSim in the module "*Wind Fields*". The default setting can be used in this module.

Note however, that the value of "Number of iterations" depends on the value of "Maximum number of cells" set in the preceding module "Terrain". The value of "Number of iterations" must be sufficiently large for convergence to be reached. The default value of 100 is usually sufficient for small models with 100 000 cells. For lager models the value of "Number of iterations" usually must be raised to several hundreds.

Climatology and turbines
The climatology and turbines are special in this championship as all participant are supposed to use the same local wind climate and the same type of turbines, see the below rules. Adding a climatology and turbines to the wind farm is done in WindSim in the module "*Objects*".

Wind Resources
The wind resource map is established in WindSim in the module "*Wind Resources*". Establish a wind resource map at the same height as the hub height of the wind turbine. It is the wind resource map which is your primary source for the optimization of the energy which follows next.

Energy
To optimize the energy production is an iterative process, where you test out many layouts. A layout defines a given positions for all the wind turbine in the wind farm. First you have to position each turbine at a windy spot. Next, the wind turbines should not be too close to each other. A wind turbine extracts a large amount of energy, leaving an area with lower wind speed on its leeside. Try to avoid placing wind turbines in these regions and thereby reduce the so-called wake losses.

In WindSim you position wind turbines in the module "*Objects*". The wind resource map and the effect of the wakes are visually explored in the module "*Wind Resources*", while the calculation of the energy production and wake losses is done in the module "*Energy*".

The software Park Optimizer is part of WindSim's software suite, which automatically optimize the layout with respect to maximizing the energy production. We will not use this software – here you should use your own skills in designing the best performing layout.

Layouts
In WindSim there is a possibility to easily compare results from various layouts. Take a copy of an existing layout, the changes you make will be saved as a new layout. Swap between the layouts to determine which is the best performing for your site.

And the winner is…
To take part in the championship send your best performing layout to us. A layout is exported from WindSim under "Tools" – "Export HTML report…", which will establish the following folder:

C:\Users\your_user\Documents\WindSim Projects\your_project\your_layout\report_export

Notice that only one layout is exported, which is the currently opened layout in WindSim when the export is done. Check that you have exported your best performing layout before you zip the whole folder and send it to us at: info@windsim.com, the subject of the email should be: "Wind Farm Design Championship".

The participant presenting the wind farm with the highest energy production (AEP, Annual Energy Production) is the winner. The list with all top designers, including their projects, will be published at http://windsim.com/library/championship.aspx

Rules and input
This is a championship in designing the best performing wind farm. You pick a location somewhere, hopefully with some favourable terrain features, which will accelerate the wind. The challenge is to understand how the wind varies and to position each turbine in a windy spot.

Rule 1 – Project specific input
In order to make this a fair competition we have to use common settings for some of the input parameters, which would affect the energy production.

The model resolution will affect the energy production. A high-resolution model will have higher extreme values compared with a low-resolution model, see figure 1.
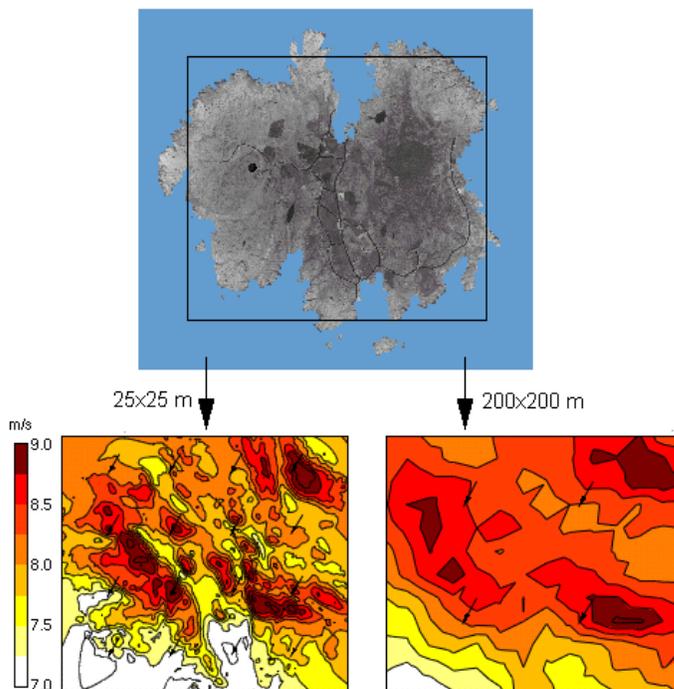
Figure 1. *Wind speeds obtained from two identical models except for differences in the resolution. The high-resolution model (left) displays higher maximum wind speed and lower minimum wind speed than the low-resolution model (right)*

Hence, in the module "*Terrain*" the property "*Maximum number of cells*" should be set to: 100 000.

It should be noted, that a numerical 3D model with 100 000 cells, is a relatively small model. Then simulations can be performed on low-end computers within a few minutes, which of course is a great advantage. However, the results obtained with such a low-resolution model is most likely not grid independent. In commercial projects a high-resolution model should be used ensuring grid independency.

Likewise, the chosen wake model will affect the energy production. Hence in the module "*Energy*" the property "*Wake model*" should be set to Wake Model 1.

Finally, the Annual Energy Production in the module "Energy" is reported in two different ways based on the representation of the climatology. The climatology is either so-called Weibull fitted or not. We choose to use the non-fitted distribution called "Frequency table" when reporting the energy production, that is the value in Table 1 in column "AEP with wake losses".

Rule 2 – Climatology and position

All participants should use the same climatology, which should be downloaded at: http://windsim.com/championship/dummy_climatology.zip

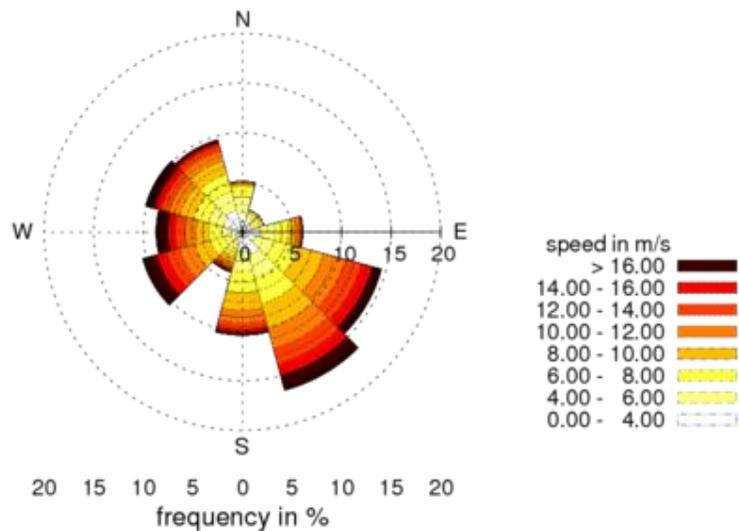The dummy climatology is originally from a location in Norway with a wide spread of wind directions, see figure 2.

Figure 2.   Wind rose for the dummy climatology

Whenever a dummy climatology is introduced in a 3D numerical model at a location where it strictly doesn't belong, that is at a location where it was not measured, then the wind resources map derived from the numerical model using this climatology will be incorrect. If the dummy climatology is introduced at a high wind speed hilltop a certain wind resource map is obtained, whereas if the same climatology is introduced down in a low wind speed valley the wind resource map would be significantly different, the latter would actually display much higher wind resources. For this reason the participants are not allowed to position the climatology in an arbitrary position.

The position of the dummy climatology will be fixed towards to the top border of your model. By default, the top border is sufficiently far away from the ground not to be influenced from terrain effects. Thereby positioning the dummy climatology at this location will introduce the same wind climate in all models.

The height of the top border is model specific, it is found in the report in the module "Terrain", see figure 3.
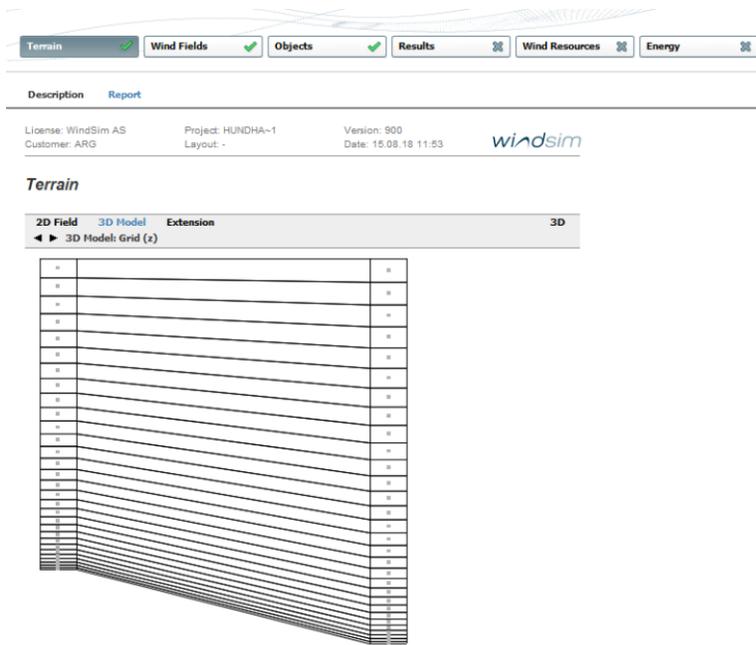
Fig 1. Digital terrain model - Grid (z).

The grid extends 976.2 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

Figure 3. *The height of the top border is 976.2 meters in this example model*

The height of the dummy climatology must be set to the height of the top border. Open the file "dummy_climatology.wws" in a text editor and replace the default value 9999.0 meters with the height of the top border, see figure 4.

```
version            : 43
site name          : dummy_climatology
measurement period : 01.01.17 - 31.12.17
site position      :          2000.0        2000.0
coord. system      :              1
measurement height :          9999.0
number of sectors  :             12
number of bins     :             40
total records      :              0
```

```
version            : 43
site name          : dummy_climatology
measurement period : 01.01.17 - 31.12.17
site position      :          2000.0        2000.0
coord. system      :              1
measurement height :          976.2
number of sectors  :             12
number of bins     :             40
total records      :              0
```

Figure 4. *The original header of the file dummy_climatology.wws (left) and corrected header (right)*

By default the dummy climatology will be positioned 2000 meters north and 2000 meters east of the lower left corner of any model. This position should remain unchanged. Figure 5 displays a typical 3D numerical model and the position of the dummy climatology, the extensions of this model is 9050 meters in west-east direction and 7550 meters in south-north direction.
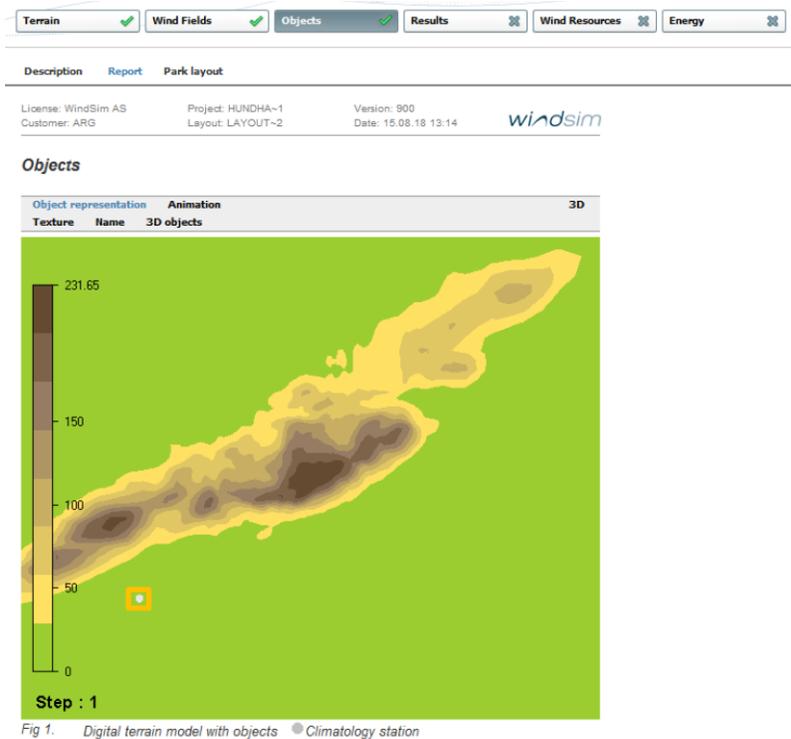
Figure 5. *Position of the dummy climatology 2000 meters north and east of the lower left corner in this example model*

Rule 3 – Wind turbine

All participants should use the same wind turbine, which is a 3MW turbine to be downloaded at: http://windsim.com/championship/dummy_turbine.zip

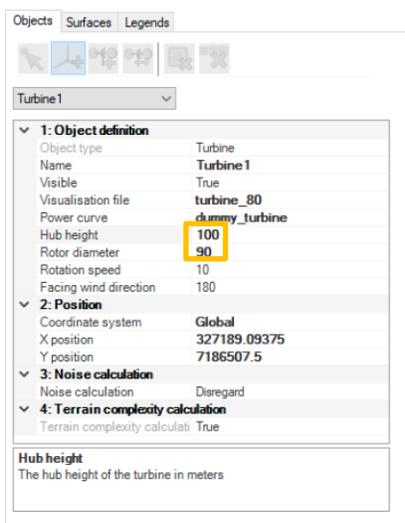The turbine height should be set to 100 meters and the rotor diameter should be set to 90 meters, see figure 6.

Figure 6. *Wind turbine hub height and rotor diameter should be 100 meters and 90 meters respectively.*

Rule 4 – Wind farm

The wind farm should consist of 10 wind turbines. The wind farm area is limited, all turbines must fit into a square of 1500x1500 meters.

Rule 5 – Feasibility

The last rule should secure that the wind farm could be build. If you position your wind farm at the top of Mount Everest, it would not be feasible to build it. There would be some practical constraints in the civil work, like road construction and erection of the turbines which we need to respect – be realistic and chose a suitable site.