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2.0 BASIS – Start-up introduction

2.0.1 Introduction to windPRO BASIS

The windPRO BASIS module is, as the name implies, the basis for all windPRO calculation modules. With BASIS users can create a project, which typically consists of background maps and WTGs (wind turbine generators - turbines) positioned on the map. Also, most of the other objects such as digital height contour lines, neighbors for noise calculations, etc., can be established from the BASIS module. In addition, the WTG Catalogue is managed through the BASIS module.

Enter all relevant information for a given wind energy project in BASIS, and use the WTG Catalogue to get detailed technical information for most of the wind turbines on the market and for adding new turbines to the WTG Catalogue, e.g. for documentation and comparison purposes.

The calculations you can carry out depend upon which windPRO calculation modules you have purchased. Non-activated modules can operate in DEMO mode, which means that you can input data, print reports (e.g. from the samples), but you cannot perform calculations.

Sample projects containing various calculations can be downloaded directly from windPRO.

2.0.1.1 Quick guides

Multiple quick guides are available at help.emd.dk. There you can find tutorials on how to start your first project, how to clean measurement data, how to run various energy calculations and much more. These quick guides take you through different topics of windPRO step-by-step. Additionally, visit YouTube for webinars and demonstration videos.

2.0.1.2 Conversion of previous projects

There is an almost full backwards compatibility to windPRO projects created in the very first versions. In general, older windPRO projects can be opened with the latest version, and conversion of data structures that might need revision will be performed. In the latest version, there is a “save as” feature allowing for saving in the format of the previous version.

In case of version conversion problems, please contact windPRO hotline, and the team will do what is possible to help you out.

2.0.1.3 File type overview

By default, all windPRO 3.6 files are located in the folder \windPRO Data\Projects\…

The two main windPRO formats are:

*.w36p – windPRO 3.6 project file – holds data stored in objects, calculation reports and links to files.

*.~w36p – backup of windPRO 3.6 project file – is created when an opened project is saved and is a backup of the opened project. This gives you the opportunity to revert to the original project file if your PC or software should "break down" during the saving process and damage your project file.
For older versions, the project file and back up file have the same structure as presented above. Only the file extension differs, as follows:

Version	Project file extension	Backup file extension
windPRO 3.5	*.w35p	*.~w35p
windPRO 3.4	*.w34p	*.~w34p
windPRO 3.3	*.w33p	*.~w33p
windPRO 3.2	*.w32p	*.~w32p
windPRO 3.1	*.w31p	*.~w31p
windPRO 3.0	*.w30p	*.~w30p
windPRO 2.9	*.w29p	*.~w29p
windPRO 2.8	*.w28p	*.~w28p
windPRO 2.6 – 2.7	*.w3p	*.~w3p
windPRO 2.0 – 2.5	*.w2p	*.~w2p

Version	Export file extension
windPRO 3.5	*.w35e
windPRO 3.4	*.w34e
windPRO 3.3	*.w33e
windPRO 3.2	*.w32e
windPRO 3.1	*.w31e
windPRO 3.0	*.w30e
windPRO 2.9	*.w29e
windPRO 2.8	*.w28e
windPRO 2.6 – 2.7	*.w3e
windPRO 2.0 – 2.5	*.w2e
windPRO 1	*.wpe

Export file extensions, corresponding to different windPRO versions are presented below. During the export process, users can select which data to include in the file (e.g. bitmap maps).

Other file types used in windPRO:

*.bmi - Binary map info. Coordinate settings for user-defined or online maps. When a local coordinate system is used, it can be imported to another project from a BMI file.

*.bx - Bitmap maps with coordinates defined in a BMI file. In the current version the files are saved in a PCX format. "x" is the file number, starting with "0" for the first one.

*.wpo – Digitized lines from Line Object – holds height contour or roughness lines plus a digital elevation model (Triangular Irregular Network (TIN)).

*.wpg – Digital elevation data as gridded data saved from the elevation grid object – holds regularly-spaced digital elevation points, can hold more layers with different grid resolutions.

*.w2r – windPRO regions – digitized polygons from Area Objects.

*.lty – Landscape types for windPRO Area Object. The landscape types are included in the .w2r files, but the .lty files makes it possible to exchange the definitions with other .w2r objects.

External file types (data from other sources), used within windPRO:

*.map – WAsP map file format for digitized height contour and/or roughness lines.

*.rsf – WAsP Wind Resource Map.

In the folder \windPRO Data\Standards:

*.EMDLayout – windPRO windows layout.
*.wla – predefined object layers setup.
*.wmi – meteo import filter.
*.wbs – WINDBANK input file (template or complete input data file for economy calculation).
*.wsd – Solar and/or wind distribution for SHADOW calculation.
*.linecolorsetup – windPRO color setting.
*.rastercolorsetup – windPRO color setting.

*.noisemapsetup – windPRO color setting for specific country and model.
*.flickermapsetup – windPRO color setting for specific country.
*.lty – Landscape types
*.wti – Wind time variation file to use for time varying AEP calculations and loss calculations. There will be some example files included that can be used.

In the folder \windPRO Data\Windstatistics:

*.wws – windPRO Wind Statistics. Binary equivalent to LIB files, in addition to the Wind Statistics information, it contains information about country, coordinates, creation time, source, elevation, height and other info on the basis for the wind statistic. Also user comments written when the wind statistic is saved are included. File type can be locked so a license key is required to use the file (see Chapter 3).

*.LIB – Wind Statistics in Risø's WAsP format (when saved from windPRO, coordinate information is included) (see Chapter 3).

*.GWC - Wind Statistics in WAsP 11 format, (see Chapter 3).

In the folder C:\windPRO Data\WTG data:

*.wtg – Wind turbine file – holds all relevant data of a specific wind turbine, such as WTG type, defined from manufacturer, type-designation, rated power (kW_{nom}-kW_{small}), rotor diameter and tower type.
A typical name: **VESTAS V112-3.6 3600 112.0 !O!.wtg**, Where "!O!" means tubular tower, !#! means lattice tower, "!3!" mean tripod tower and "!-!" means unknown or other tower type. All information is integrated in a file, which is flexible enough to hold multiple sets of data, e.g. power curves, noise data, etc. In the .wtg files from EMD, the power curves etc. are integrated in the .wtg file. If the user adds some data, these will be placed in a separate file so an update from EMD can update previous data without destroying the user-added data.

*.uwt – User-defined wind turbine file, which holds additional data to the .wtg file, added by the user. Note: The .uwt file only works together with a .wtg file with exactly the same name. If you want to send turbine data to another user, BOTH files must be copied.

*.wbl – windPRO blade file, defines the shape of a blade for visualization purposes.

File created by windPRO:
*.wpobjects – export of one or more windPRO objects (including coordinates and attached files).

Other relevant file formats:
*.shp – Shape file (from Arc View GIS software) – polygons, lines or points that can be imported to, or exported from, windPRO.

*.dae - file format based on COLLADA, making it possible to import 3D graphics files and use in visualizations.

*.dxf – Auto desk exchange file format (AutoCAD) – can be digitized height contour lines, which can be imported in the Line Object or can be drawings of e.g. high voltage mast or lattice WTG-towers, which can be used for visualization purposes.

*.ntf – From the UK Ordinance Survey, digitized height contour lines can be imported in the Line Object or gridded terrain data that can be imported into an Elevation Grid Object.

*.kmz – Google Earth files can be imported in windPRO. In the same manner a .kmz file can be exported from windPRO to Google Earth.

.cfdreq – Output file from windPRO for WAsP CFD

.cdfres – Result file for input to windPRO from WAsP CFD

.flowreq - Output file from windPRO, to be used in third party CFD software such as OFWind (link)

.flowres - Result file from third party CFD software to be used as input in windPRO (link)

.siteres – A generalized output format containing a complete set of modelled flow conditions for use in optimization models and site-compliance analyses (link)

.optireq – Output file from windPRO, to be used in third party optimization software [GIRAFFA] (link)

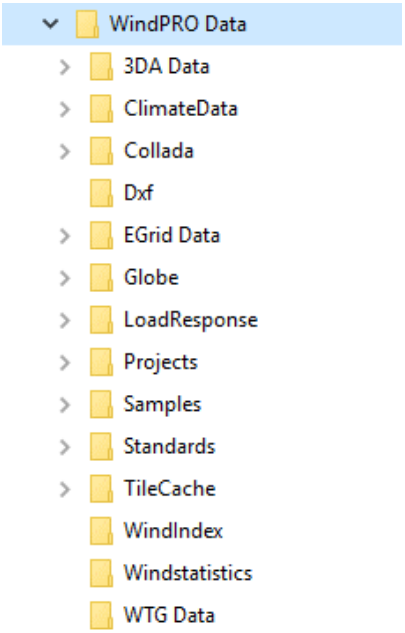
.optires – Result file from third party optimization software [GIRAFFA] to be used as input in windPRO (link)

.PowerMatrix – A file format containing multiple climate-dependent power curves, ct curves, operational modes and noise data for a specific turbine model. (link).

2.0.1.4 Proposed way to organize data

We recommend that you create a folder in \windPRO Data\projects\ for each new project (or group of projects in same region or for the same client). In this folder, the project file (*.w35p) is stored as well as all other elements used in the project, such as the local bitmap maps, digitized files, e.g. height contour maps, measured wind data, generated Wind Statistics, photos for visualization, site specific WTG-types etc. Hereafter it is always possible and recommended to have all data in the same folder. This ensures that the backup file will incorporate the entire project, and makes it easier to hand over a complete project to other windPRO users.

Below, the structure of default sub-folders to windPRO Data is shown:



For Wind Statistics and WTG-types that you might use for other projects, it's recommended to store a copy in the folders:

\windPRO Data\WTG Data
\windPRO Data\Windstatistics

If you are connected to a server and need to have files there for sharing of data with other employees, you simply create a folder on the server and add this folder to your Project Browser (and WTG and Wind Statistics Browsers). This folder should have exactly the same structure as the one described above, which makes it easier, e.g. when you want to move projects from the server to your local PC or Laptop for travelling.

Note: In the windPRO project file (*.w35p), all files, which cannot be found in the original folder will be searched for and, when found, replaced automatically in the actual project folder or sub-folder to this (working directory).

The mentioned rules of addressing files mean that links to data (for example folders with WTG Data or wind statistics) will be replaced with links on the new PC if project files are moved from one PC to another.

If you always want to use WTG Data from a common server, make sure that only a search path for this is specified in the WTG Explorer.

To be completely sure that you are working with exactly the same files as your colleague, but from another PC, make an export file (from menu Project-> Export) with all files included and open them from your own PC, or work directly with the project files placed on a common server version.

2.0.2 Recommended hardware and auxiliary software

Hardware	
PC	windPRO 3.6 supports 64-bit versions of Windows 7/8/10/11
Digital camera	A digital camera is useful for photomontages or for general documentation of the site. Most cameras store EXIF information about focal length and exposure date & time which windPRO automatically reads into a camera object when preparing photomontages. In case no EXIF information is available, you should know the exact focal length of the lens in 35 mm film equivalent. Around 45-50 mm is closest to the human eye's "focal length" and preferred by many as "fixed lens", however always check the local regulations relating to photomontage photography. Some of the latest cameras store GPS coordinates for the photo position and even the bearing along which the photo is taken. This makes it even easier to make a photomontage with windPRO.
A GPS unit	A useful GPS device for acquiring coordinates of objects (e.g. existing turbines, measuring mast positions, photographers' positions) in fieldwork.

Auxiliary software	
WAsP v.6.0+ (from Risø/DTU)	Energy calculation engine used by windPRO. There are some differences from WAsP 9 to later versions (a separate note on this topic can be found at help.emd.dk). WAsP 11 and later includes a CFD model that can be called from windPRO, subject to the purchase of CFD credits. WAsP 11 is needed for utilizing the new time-step based energy calculation concept based on a SCALER (see Chapter 3 Energy).
WEng (WAsP Engineering) v3.0+(from Risø/DTU)	For the Site Compliance module WEng can contribute with valuable calculation options in turbulence and extreme wind calculations. Latest version recommended!
WAsP CFD, OF.Wind or other CFD software	To increase the accuracy of the energy calculation in complex terrain, it is recommended to use a CFD model. CFD results from a wider range of models can be read and used in the calculations. WAsP CFD can be operated directly through windPRO. CFD credits can be purchased from EMD.
SketchUp (from Trimble)	For generating your own 3D models to be used for visualizations. Models can be exported as .dae files from SketchUp and these can be imported into windPRO.

An image editor e.g. Paintshop PRO, Photoshop etc.	For stitching photos together into a panorama for photomontage. For re-powering projects, you can erase existing turbines from a photo.
A PDF viewer	windPRO can save reports as .pdf files which can be previewed directly in the pdf viewer.
Google Earth PRO	Synchronize Google Earth with windPRO to view or present the project (wind turbines, noise points, etc.) in a 3D terrain model based on aerial photos. Photos from Google street view can also be imported for photomontages.

2.0.3 Getting started – language selection, etc.

To start windPRO, open the Windows Start menu and find “windPRO-3.5 language selection” or just “windPRO”. It’s always worth creating a short-cut on your desktop, start menu or taskbar. windPRO-3.5 language selection lets you choose which language to use as default when starting windPRO (if more language modules are purchased). To start with a specific language, click on the flag. Unlicensed languages can be started in DEMO mode.

2.0.3.1 Report language

Calculation results can be presented in reports in a language other than the one you are working in. To use this feature requires a Print Language module.

2.0.4 Online data services

We continuously put a large effort in providing valuable data sources for wind energy project development in windPRO. Many (freely) available online sources can be very difficult to extract, and often it requires engineering expertise to understand and convert the data to something that can be used. windPRO does all this for you, so you are only a few clicks away from useful data.

At present there are the following online data sets:

- Background maps (See Project properties, EMD Online maps sources)
- Elevation data (See Line object, EMD Online elevation data sources)
- Surface roughness data (See Area object, EMD Online roughness data sources)
- Meteorological data (Chapter 12, section 12.3.1, EMD Online Wind data, EMD Mesoscale data)
- Existing turbines, position, type and actual production (See Importing existing turbines, EMD Online Existing Turbines databases)

Besides, we have the comprehensive wind turbine catalogue, which we do not refer to as an online service, as the catalogue is built and maintained solely by EMD. The catalogue can be updated from the update button in the turbine catalogue and users can add their own entries.

2.0.4.1 Availability of online data for older windPRO versions

The Online data services are quite comprehensive to maintain, giving EMD host servers an extremely large amount of data. So, the Online servers at EMD are frequently (every 1-3 years) updated. When this happens, EMD no longer updates older versions of windPRO with the latest updates made in the online data services. This means having continuous access to online data services can only be guaranteed if you have the latest version of windPRO. EMD tries to keep the service alive for older versions, but this cannot be guaranteed. Typically, the phase out of the data service happens a year after the release of the new version of windPRO. Users are warned of the imminent removal of such data.

2.0.6 Auto save / recovery

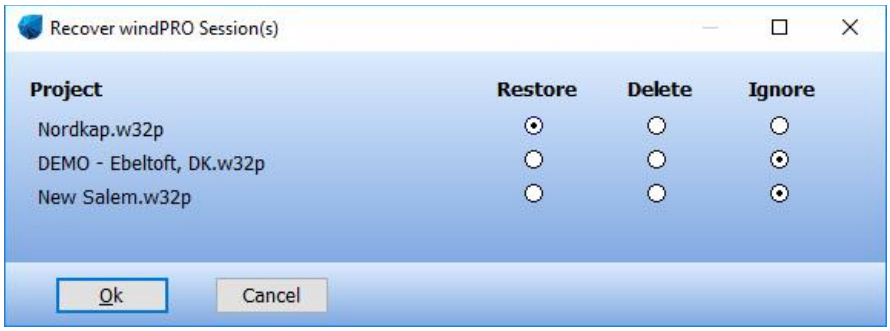
windPRO has an automatic auto save feature. This runs each time a calculation is performed and is also triggered by several other events. It checks when the last auto save ran, if less than 3 minutes it won't run again, disturbing as little as possible. If the software or the PC crashes, a restart of windPRO will ask if you want to open the recovery file.

You can also load the backup file, the project file that was opened last, by choosing the *.~wXXp file.

2.0.6.1 Working with multiple instances of windPRO

In previous versions of windPRO only a single project could be open at a time.

From windPRO version 3.2 multiple projects can be open simultaneously, even across versions. This means each project has its own recovery file. In case multiple windPRO projects are improperly closed, a recovery window will appear the next time you open windPRO:

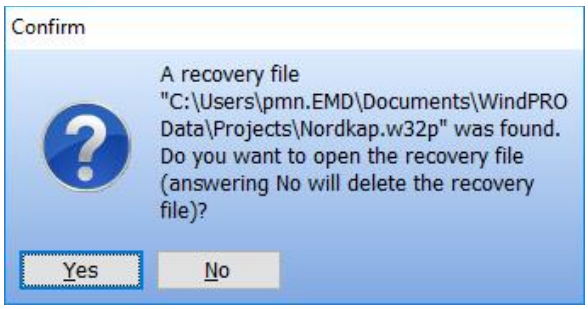


Restore: Open windPRO with this project in recovery mode – this will be like answering YES in the old recovery dialog. Only one project can be recovered at a time.

Delete: Delete the recoverable project from disk. It will NOT be possible to recover that project again. The last saved copy of the project is, of course, not deleted.

Ignore: Ignore the recoverable project for now. The next time you open windPRO, this recovery window will open again, so you can decide later what to do with that project.
The above screen will only be shown if you have more recoverable projects.

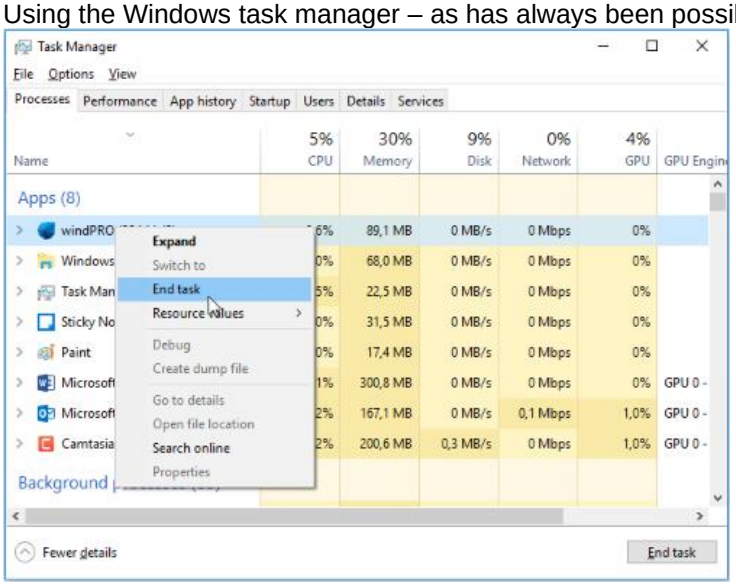
If there is only *one* recoverable project this dialog will be shown:



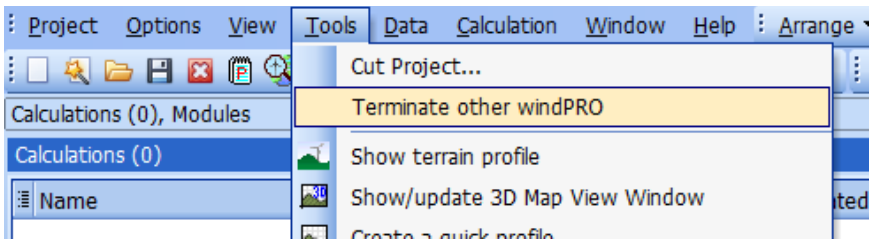
2.0.6.2 Force closing windPRO

Before windPRO version 3.2, a windPRO instance could be forcibly closed by opening a new instance of windPRO. This is no longer the case. Instead, you have two options for forcibly closing existing windPRO instances:

1) Using the Windows task manager – as has always been possible.



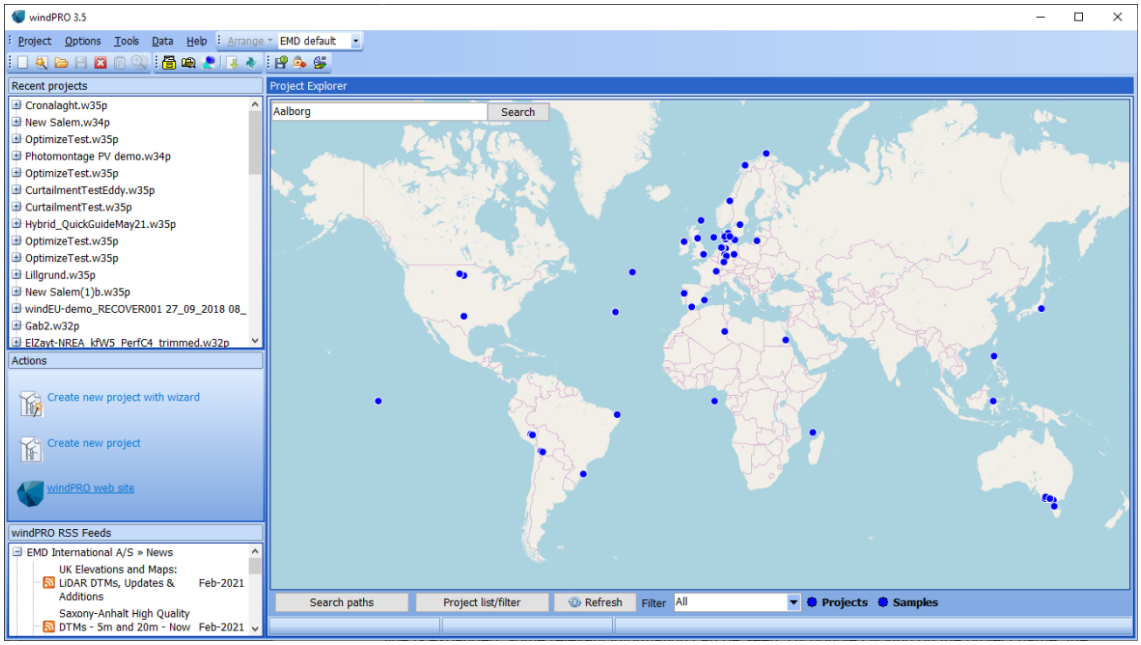
2) Using the built-in **Terminate other windPRO** button in windPRO.



Using this option, you will not be able to terminate the current windPRO instance (but you can open another instance to do this). For windPRO instances which have a project open, the project name will be listed.

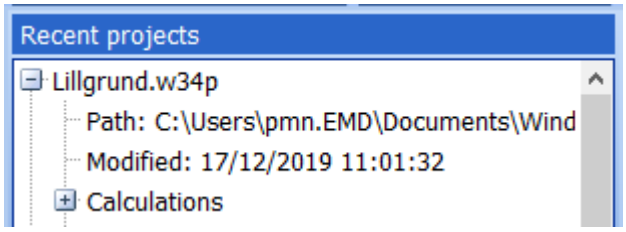
2.1 BASIS- Project Manager (Starting screen)

2.1.1 Introduction to the Starting screen

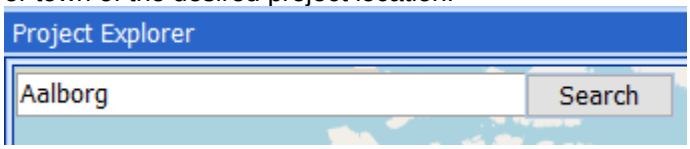


The starting screen of windPRO is divided into several parts. It allows users to get an overview of the most recent projects opened in windPRO, to view the projects on the globe with the Project Explorer or to start a new project (with or without the wizard) or on the globe. The Project Explorer is described in the next section. The other parts of the starting screen are presented below.

Recent projects: this window provides a list of the most recently opened projects. When the project line is expanded, some relevant information can be seen. By double clicking on the project name, the windPRO project is opening.



Actions: A new project can be created by clicking on “Create new project” and optionally using the wizard (see Project Wizard). Alternatively, double click on the location on the map to start a new project there. Use the small search bar in the upper left cover of the map to search for the nearest city or town of the desired project location:



Below, the link to windPRO web site allows the user to check the different windPRO modules, the upcoming courses or which fairs EMD will exhibit at.

windPRO RSS Feeds: RRS feeds show the latest news of EMD International A/S (related to windPRO), the latest updates available from windPRO online help and announcements of upcoming windPRO courses around the world.

2.1.2 Project Explorer – map and globe navigation

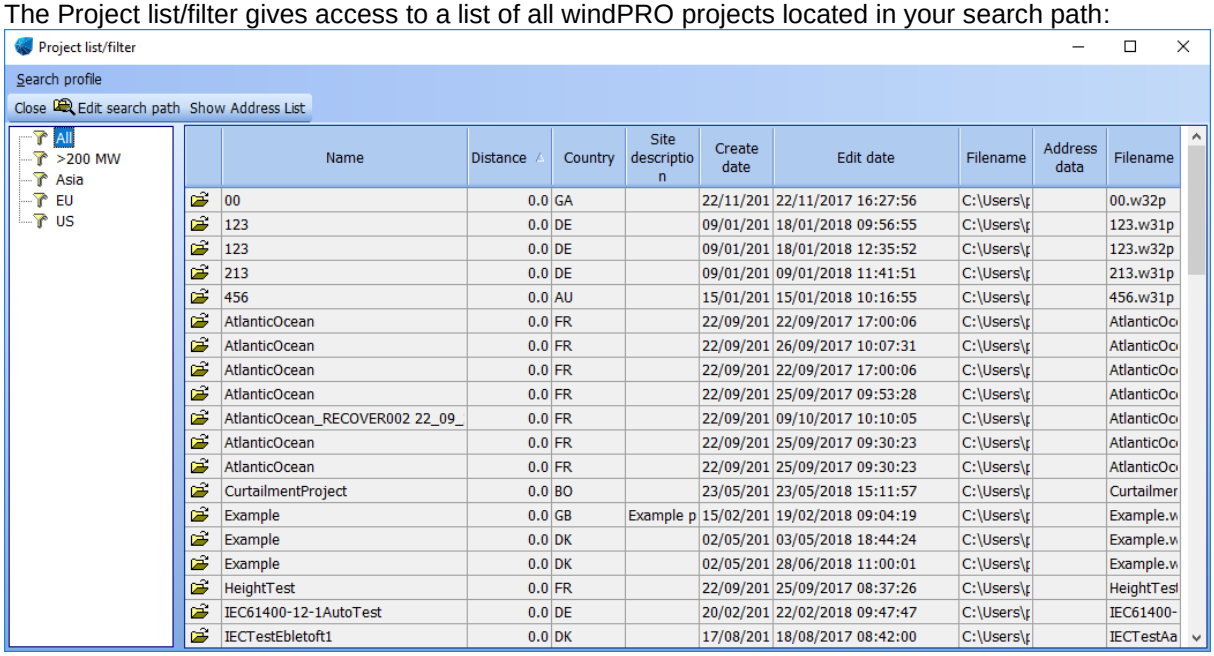
The colored dots on the map are projects which are found in the search paths defined at the bottom of the screen. It is possible to assign different colors to each search path to better organize the project view (see Search Paths).

Projects are opened from the Project Explorer by double clicking a dot on the map. To start a new project, simply double click on the desired located on the map. The site center of the project will correspond to the position where the double click was made on the globe. This position will likely need to be adjusted later on (see Project Properties and Maps).

The Project Explorer can be accessed any time from a project via the Project Explorer button:

The refresh button refreshes your project list (colored dots on the map), if you e.g. copied some projects with the Windows Explorer into your Project Explorer search path or if connected to a server with additional projects.

The Project list/filter gives access to a list of all windPRO projects located in your search path:



	Name	Distance	Country	Site description	Create date	Edit date	Filename	Address data	Filename
	00	0.0	GA		22/11/201	22/11/2017 16:27:56	C:\Users\		00.w32p
	123	0.0	DE		09/01/201	18/01/2018 09:56:55	C:\Users\		123.w31p
	123	0.0	DE		09/01/201	18/01/2018 12:35:52	C:\Users\		123.w32p
	213	0.0	DE		09/01/201	09/01/2018 11:41:51	C:\Users\		213.w31p
	456	0.0	AU		15/01/201	15/01/2018 10:16:55	C:\Users\		456.w31p
	AtlanticOcean	0.0	FR		22/09/201	22/09/2017 17:00:06	C:\Users\		AtlanticOc
	AtlanticOcean	0.0	FR		22/09/201	26/09/2017 10:07:31	C:\Users\		AtlanticOc
	AtlanticOcean	0.0	FR		22/09/201	22/09/2017 17:00:06	C:\Users\		AtlanticOc
	AtlanticOcean	0.0	FR		22/09/201	25/09/2017 09:53:28	C:\Users\		AtlanticOc
	AtlanticOcean_RECOVER002 22_09_	0.0	FR		22/09/201	09/10/2017 10:10:05	C:\Users\		AtlanticOc
	AtlanticOcean	0.0	FR		22/09/201	25/09/2017 09:30:23	C:\Users\		AtlanticOc
	AtlanticOcean	0.0	FR		22/09/201	25/09/2017 09:30:23	C:\Users\		AtlanticOc
	CurtailmentProject	0.0	BO		23/05/201	23/05/2018 15:11:57	C:\Users\		Curtailmer
	Example	0.0	GB	Example p	15/02/201	19/02/2018 09:04:19	C:\Users\		Example.w
	Example	0.0	DK		02/05/201	03/05/2018 18:44:24	C:\Users\		Example.w
	Example	0.0	DK		02/05/201	28/06/2018 11:00:01	C:\Users\		Example.w
	HeightTest	0.0	FR		22/09/201	25/09/2017 08:37:26	C:\Users\		HeightTest
	IEC61400-12-1AutoTest	0.0	DE		20/02/201	22/02/2018 09:47:47	C:\Users\		IEC61400-
	IECTestEbletoft1	0.0	DK		17/08/201	18/08/2017 08:42:00	C:\Users\		IECTestAa

From the project list you can create search profiles to filter projects with certain attributes like country, edit date or directory by clicking **Search Profile** and **New**.

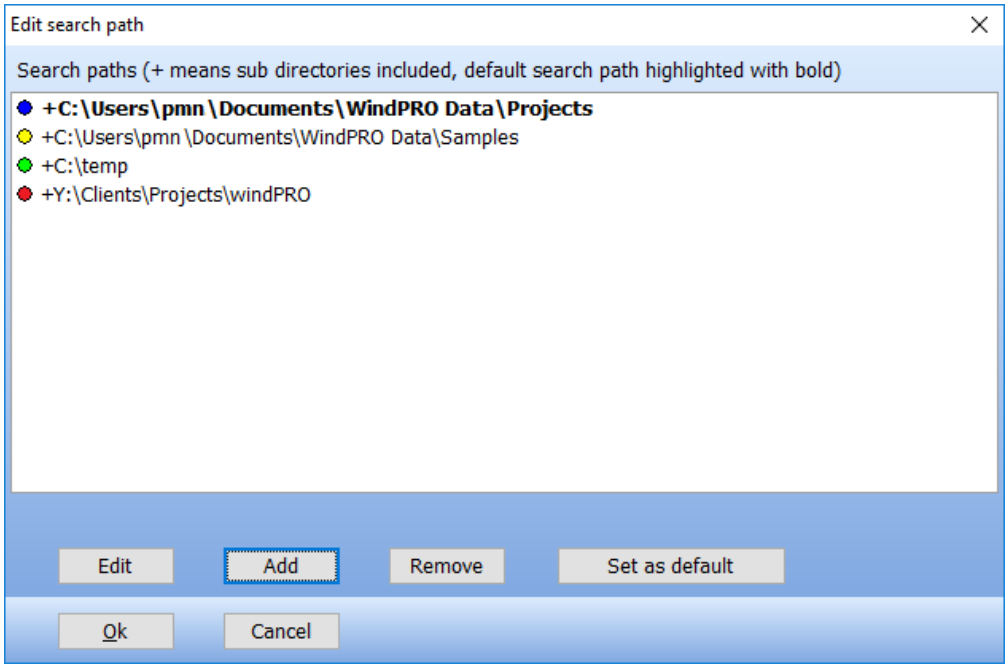
Once a search profile has been created it filters the list of projects, and also can be selected next to the map, to show only the filtered projects on the map.

2.1.3 Search Paths

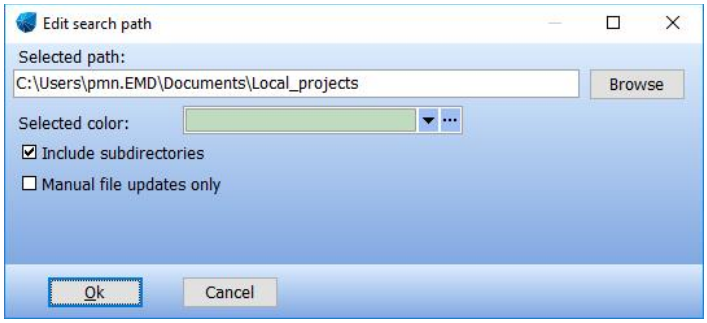
windPRO allows users to save files in different locations. Therefore, when a file has to be selected, several Search Paths can be defined in order to browse in many folders. The Search Paths option appears in the following places:

- Project Explorer (to select a windPRO file)
- WTG Catalogue (to select a wind turbine file)
- eGrid Catalogue (to select transformer and cable data)
- Site data object (to select a Wind Statistics)

Therefore, a common review is given here in general terms.



Adding locations on the local disk(s) or network gives access to the project you may want to see or work on, without searching through multiple paths and files every time you open windPRO. When adding a new search path, a color can be specified which will determine how the file is shown on the map/globe.

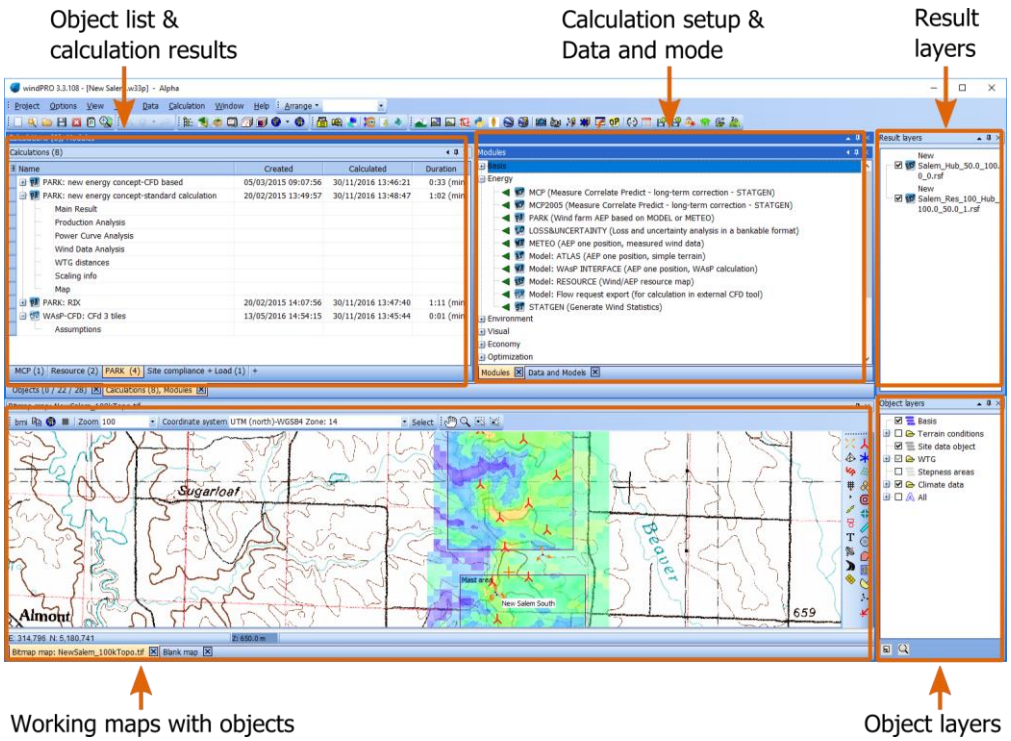


A Search Path can be edited. By default, the subdirectories are included.

2.2 BASIS – windPRO overall structure

2.2.1 windPRO structure – System overview

windPRO consists of multiple work areas:



You can jump to each section here:

- Objects
- Calculations, Modules
- Modules
- Data and models
- Maps
- Result layers
- Object layers
- Arrange windows

windPRO can add the following objects to a map:

Objects	Notes	More info in chapter
New wind turbine	>1000 turbine models in catalogue	2: Basis + 3: Energy
Existing turbine	For e.g neighboring wind farm	2: Basis + 3: Energy
Park design object	Design regular turbine layouts	8: Optimization
WTG area object	Define polygon to place turbines	8: Optimization
Line object	Height and roughness contours + photomontage	2: Basis + 7: VISUAL
Area object	Height and ZVI polygons + photomontage	2: Basis + 7: VISUAL
Obstacle objects	Wind + noise obstacle rectangle	3: Energy + 7: VISUAL
Site data object	Store site specific settings	3: Energy
Noise sensitive area	Polygon or Point	6: Environment
Elevation Grid object	Height data container	2: Basis
Shadow/Glare Receptor	Polygon or Point	6: Environment
Meteo object	Store and analyze wind data	12: Meteorological data handling
Camera object	Add images for Photomontage	7: VISUAL
Control point	GPS marker, control point for photomontage	2: Basis + 7: VISUAL
3D object	Add 3D models for Photomontage	7: VISUAL
eGrid objects	Collection of grid objects	9: eGRID
Ruler object	Measure distances	2: Basis
Shape object	Draw figures on map	2: Basis
Text object	Enter text label on the map	2: Basis
Radar object	Define radar positions	6: Environment
Road object	Draw roads, cutting and filling terrain	2: Basis
PV objects	Define area to fill with PV panels	14: Solar PV

windPRO also includes:
Calculations: Energy, MCP, Loss & Uncertainty, Loads, economy and much more.
Reports: As PDF or Result-to-file for detailed analysis
Data sets: Standards, wind statistics, climate data base, transformer data, turbine models…

Downloadable data: Background maps, elevation data, surface roughness, Meteorological data, existing turbines and On-demand Mesoscale wind data

Tools: Terrain profile viewer, 3D terrain viewer, Road profile viewer

The structure of windPRO consists of:

- A starting window, the Project Explorer where a new project can be created or existing ones viewed and started.
- The windPRO window divided in several sub windows (Objects, Calculations, Modules, Data & Models, Result layers, Maps and Object layers)
- Data sets included in the installation of windPRO or available online.
- Various tools for helping with the analysis

Input to the program is given in the following items:

Project Properties, where the general project information is entered (name, project description, client, coordinate system and any associated map).

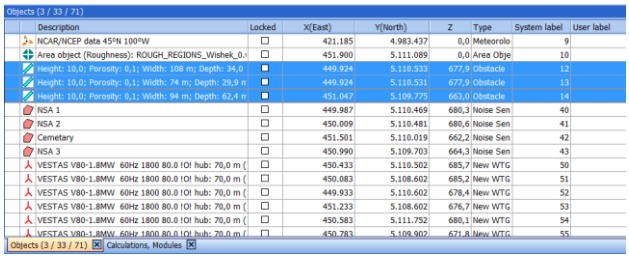
On the map and object list sub window: specific conditions for the project are entered (wind turbine positions, wind turbine type, information on calculation of wind conditions, noise conditions, etc., depending upon the type of calculations desired).

Calculation modules. When a calculation module is activated you can restrict the calculation to selected objects from the object/map list. You are also given various choices, e.g. which calculation module to select when more than one calculation module can be used.

2.2.2 windPRO structure – sub-windows

The windPRO main window is divided in sub windows, all dedicated to a specific kind of task, data or information.

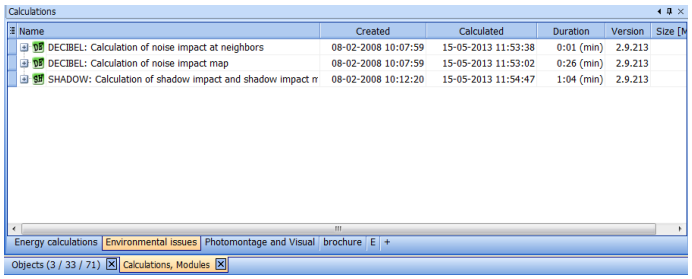
2.2.2.1 Objects



The object sub-window is the list of visible objects (according to the Object layers that are selected). Any objects visible on this list will also be visible somewhere on the map.

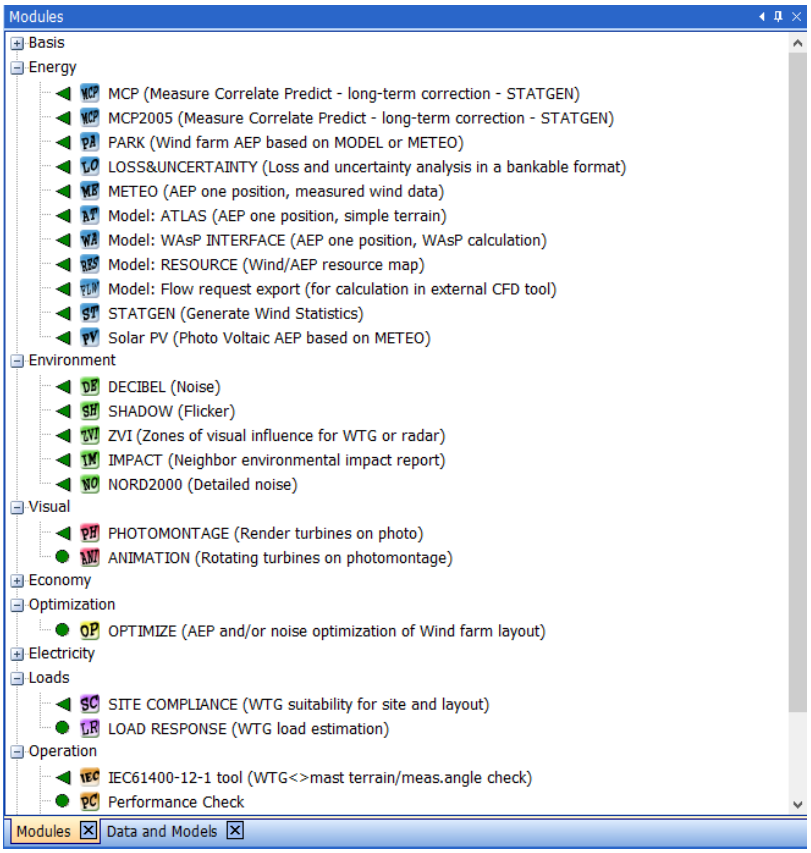
In the image above the yellow tab is called “Object (3 / 33 / 71)”. The first number in the tab refers to the number of selected objects, the second refers to the number of visible objects and the last refers to the total number of objects in the windPRO project.

2.2.2.2 Calculations, Modules



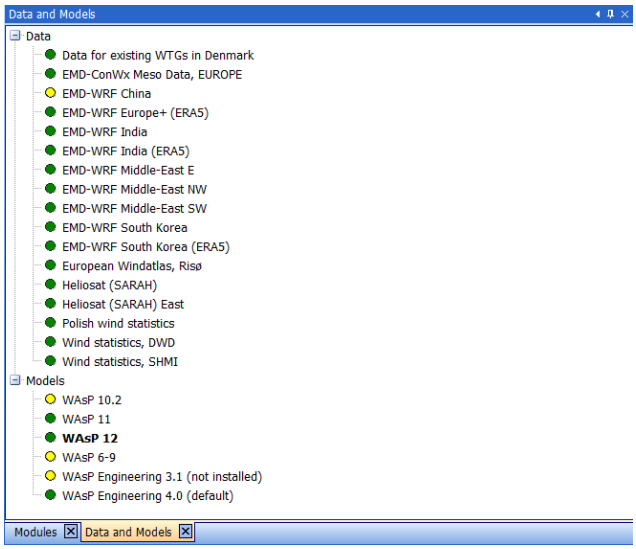
From this sub-window, the performed calculations can be seen, opened, changed, cloned, etc …

2.2.2.3 Modules



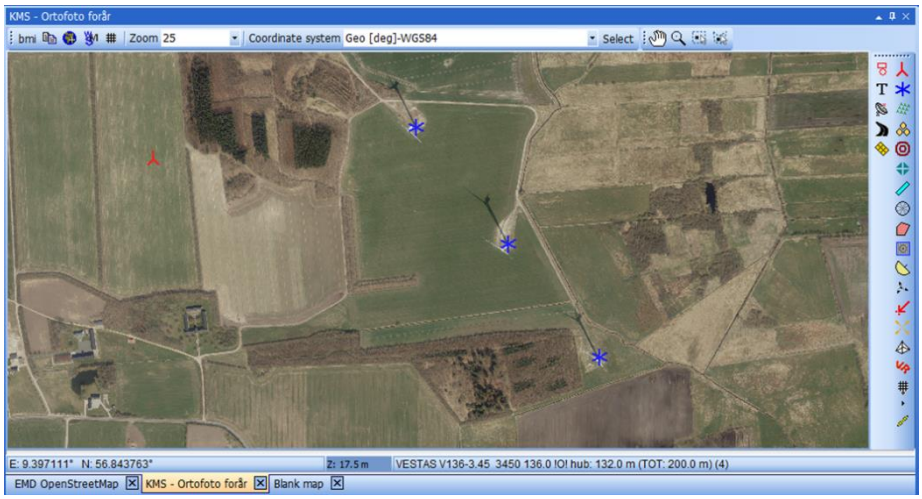
From the Module sub-window, you can start a calculation of any licensed modules (with a green triangle) by double-clicking on the module name.

2.2.2.4 Data and models

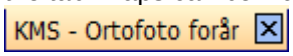


This sub-window shows which purchasable data and/or models are available to the user (green dots). Access to purchasable data is defined in the license agreement and included in the registration file. The validity of the models depends on whether the given software is licensed or not on the computer. The WAsP version in bold is the one connected to windPRO. To connect other versions, visit the Options menu.

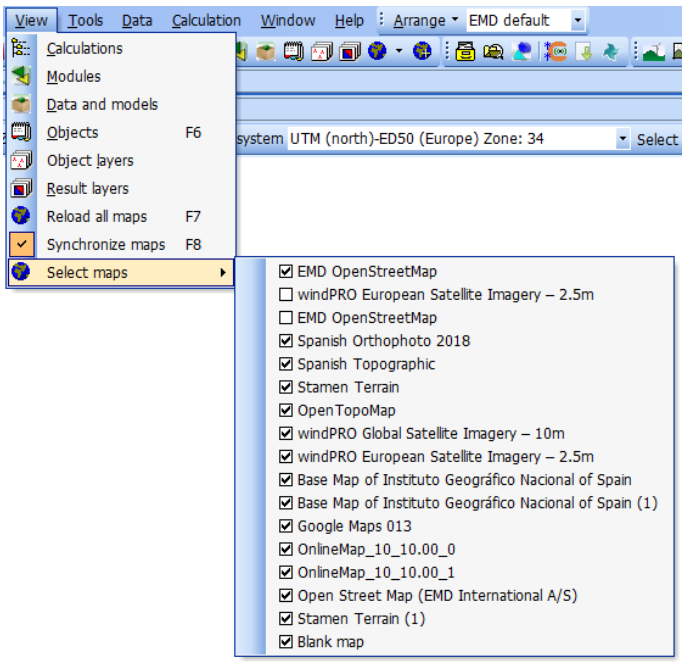
2.2.2.5 Maps



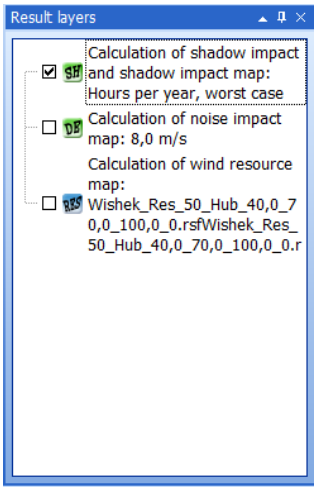
All the background maps defined in the Project Properties are presented on a specific tab at the bottom of the Map sub-window. Users can easily switch from one map to another one by clicking on the tab. Maps can be hidden with the cross on the tab:



They can be reselected from the menu View/Reload all maps or Select maps:

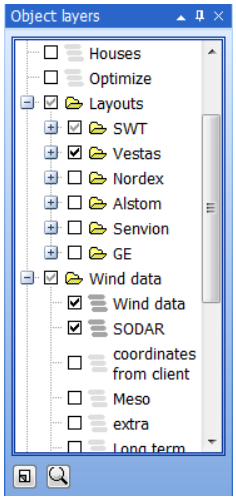


2.2.2.6 Result layers



Several calculations in windPRO (such as Resource, Noise, Shadow, ZVI) can present their results as isolines or raster data layers. These results can be loaded on a result layer in order to incorporate them in the project design. The result presented on the background maps can easily be read and analyzed. Within the result layer sub-window, several options are also available to compare or to export the data.

2.2.2.7 Object layers



The Layer structure is very useful for organizing your objects. You can save a preferred layer structure and load it in other projects by right-clicking in the layer window. The layer window can be docked into the main window.

2.2.2.8 Arrange

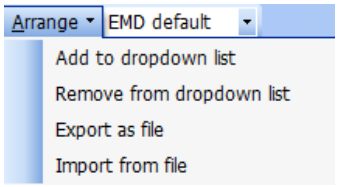
The sub-windows can be re-arranged as required. They can be moved individually. Click in the sub-window and drag it from its top bar to move it around. It becomes a standalone window (on the same or another screen) or it can be added a group of sub-windows that it is docked to.
On the top right corner of each sub-window, the arranging icons are found.

: expands or collapse the sub-window in the direction of the arrow

: pins the sub-window to the border of the main window as an orange tab. The sub-window is then active every time the cursor is moved over the tab. The tabs can be moved on any side of the main window. When the symbol is horizontal ( ) the sub-window is pinned. To unpin it, click again on the icon.

×: closes the sub-window. To open the window again, it has to be selected from the menu view. Alternatively, a window setup can be reloaded (See below).

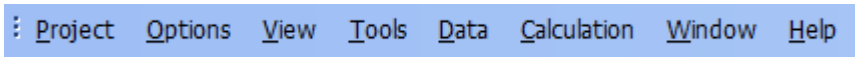
A user defined layout of sub-windows will be kept for the current windPRO session. To re-use it during another session, it has firstly to be added to the dropdown list in the Arrange menu of the available setups. When added to the dropdown list, it can be selected later on. The layouts can be adjusted to a specific type of task in windPRO or hardware configuration (laptop, one or two screens). Some pre-defined set-ups can be imported using the Arrange menu:



A layout can easily be shared between different users thanks to the Export and Import options. The format of an exported layout is *.EMDlayout. Some predefined layouts are available in the windPRO data/ Standard folder.

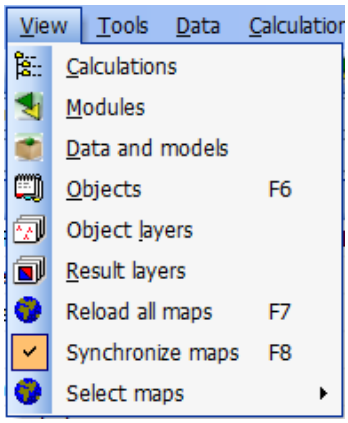
2.2.3 windPRO structure – Menus

In this section, an overview of the menus is given. Note that by pressing the <Alt> key (if activated in your windows setup), all menus can be activated from the keyboard by pressing the underlined letter when the <Alt> key is held down.



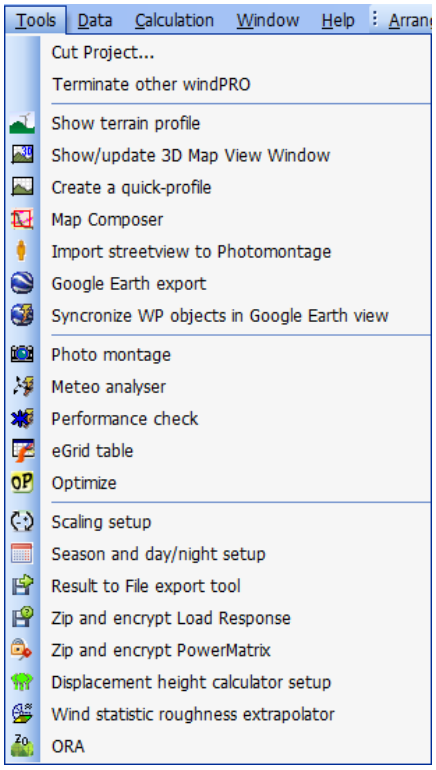
- **Project**, is where you find open, save, project properties and the Project Explorer
- **Options**, is where you change settings, handle activation of module and see the status of cluster services (CFD calculations etc)
- **View**, is where you can re-open previously closed sub-windows
- **Tools**, holds a large number of useful tools to be used at various times during project work
- **Data**, holds tools to download data such as turbine positions, sample projects and to view the wind turbine catalogue.
- **Calculation,** contains batch actions for the selected calculations in the calculation sub-window.
- **Window,** shows a list of all the windows which are not hidden.
- **Help,** shortcuts to the windPRO knowledgebase, support and bug reporting

2.2.3.1 View menu



The View menu holds some of the most important sub-windows in window. This menu is particularly relevant if you close any sub-windows and wish to open them again. Note the shortcut for the object list (F6) and the map (F7).

2.2.3.2 Tools

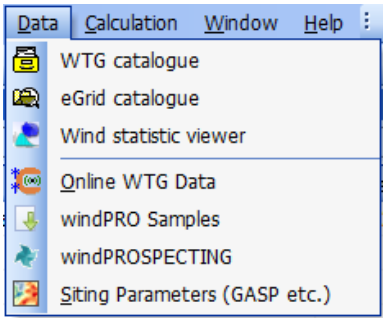


The tools menu contains many practical tools for various purposes (see Tools).

The first group above holds general tools, just requiring a BASIS license. The remaining groups are module specific tools that require a license to related modules to fully work.

The **Cut project** tool makes it possible to delete all data inside or outside a given area. If you import a large amount of GIS data or height data from other sources and only wish to work on a limited part, this is an easy way to get rid of many different types of unwanted data in one operation.

2.2.3.3 Data



WTG catalogue holds comprehensive data on all turbines.
eGrid catalogue holds data on transformers, lines and cables.
Online WTG data imports existing turbines as objects in a specified radius. The data sources are expanded over time.

WTG catalogue gives access to the comprehensive wind turbines catalogue with references of most wind turbines. The official power curves, noise, visual and electrical data can be viewed or created from scratch in the wind turbine catalogue. See BASIS - The WTG Catalogue.

eGrid catalogue holds the data of transformers and cables for eGrid calculations. See Chapter 9.

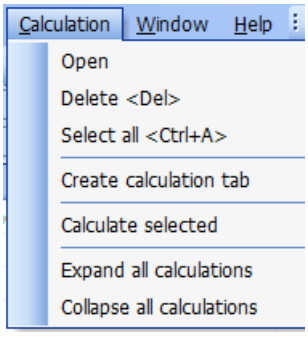
Wind statistic viewer gives access to all wind statistics available in the region of the project. Both official wind statistics and user-created ones will be available. Users can chose to search for wind statistics in a different country or region than the one of the project. The Wind statistics viewer shows information about each wind statistics, like name, creation date, energy level, number of sector used in its creation and so on.

Online WTG Data enables the users to download location and production data for existing turbines. At present, data are available for Danish, Finnish, German and US projects.

windPROSPECTING offers a spatial visualization of EMD mesoscale and global data in a web browser.

Siting Parameters (GASP etc.) is a tool to download global maps containing 250m wind resources, siting parameters & turbine design classification. See Knowledgebase which contains links to a small validation note.

2.2.3.4 Calculation

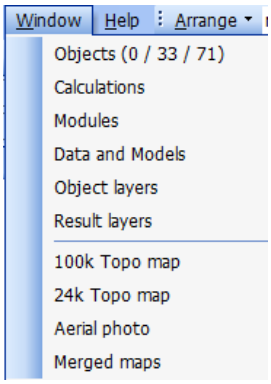


This menu is related to the existing calculations in the sub-window Calculations, Modules. All the options are also available with a right click on the selected calculation(s).

The selected calculation on the calculation window can be opened (for editing) or deleted. A calculation tab can be created to sort the calculations. Several selected calculations can be started. Finally, the calculations can be all expanded or collapsed at once.

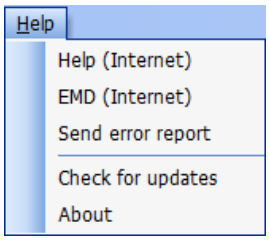
Note that the features under the calculation tab can also be managed within the calculation window (for example by a right click on the selected calculations).

2.2.3.5 Window



This menu allows switching to one of the sub-windows including the maps. Only the available sub-windows defined by the window layout are listed. If a sub-window is not available in the list, you can call it from the View menu or the relevant icon.

2.2.3.6 Help



- Help (Internet) leads to the comprehensive windPRO knowledgebase
- EMD (Internet) leads to the EMD home page.
- Send error report, if you want to report an error to EMD about windPRO. Information about the installation of windPRO on your computer is included in the error report.
- Check for updates will check if any new version of windPRO is available.

If you have subscribed for a service agreement, the windPRO support team is ready to answer any question you may have at support@emd.dk or by phone.

2.2.4 windPRO structure – Icons

The different icons in the tool bar are shortcuts to items in the menu above: Project, View, Data and Tools:

Additionally, there is an undo-group:

Undo
History of actions available to Undo
Re-do

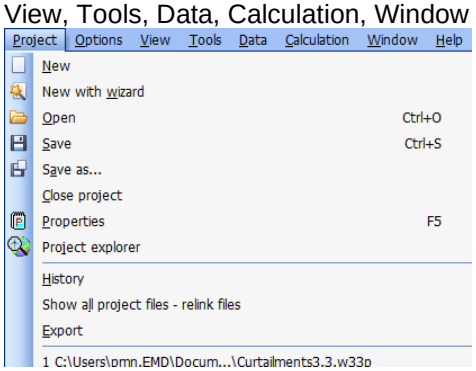
When Undo is selected, a message pops up to inform about the action concerned by the Undo. The message can be avoided next time, when the option “Keep showing warning before executing undo/redo” is unchecked. In order to reactivate the warning, go to the menu Options | Options | Misc and check Reset to default:

When several changes are made inside an object (like the wind turbine), the Undo function is applicable only when the object is closed and will then apply for all the changes made. As well when using Edit mode (of line or area objects), the Undo function can be used only at the end of the edit and is applied to all changes at a time. Note that when Apply is available and used (like in the Meteo object), the Undo function can then undo all actions since last time Apply was hit.

2.3 BASIS - General functions, setup and help

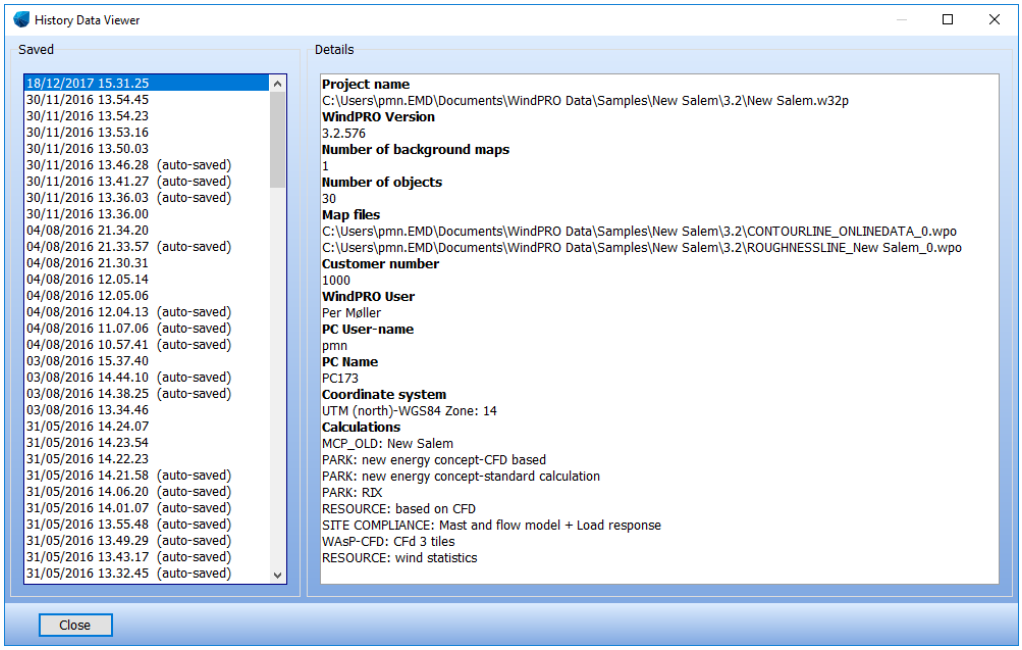
2.3.1 Introduction to general functions and setup

A description of the main features which can be found in the menu boxes under Project, Options, View, Tools, Data, Calculation, Window and Help, from the top menu bar is presented below.



2.3.1.1 History

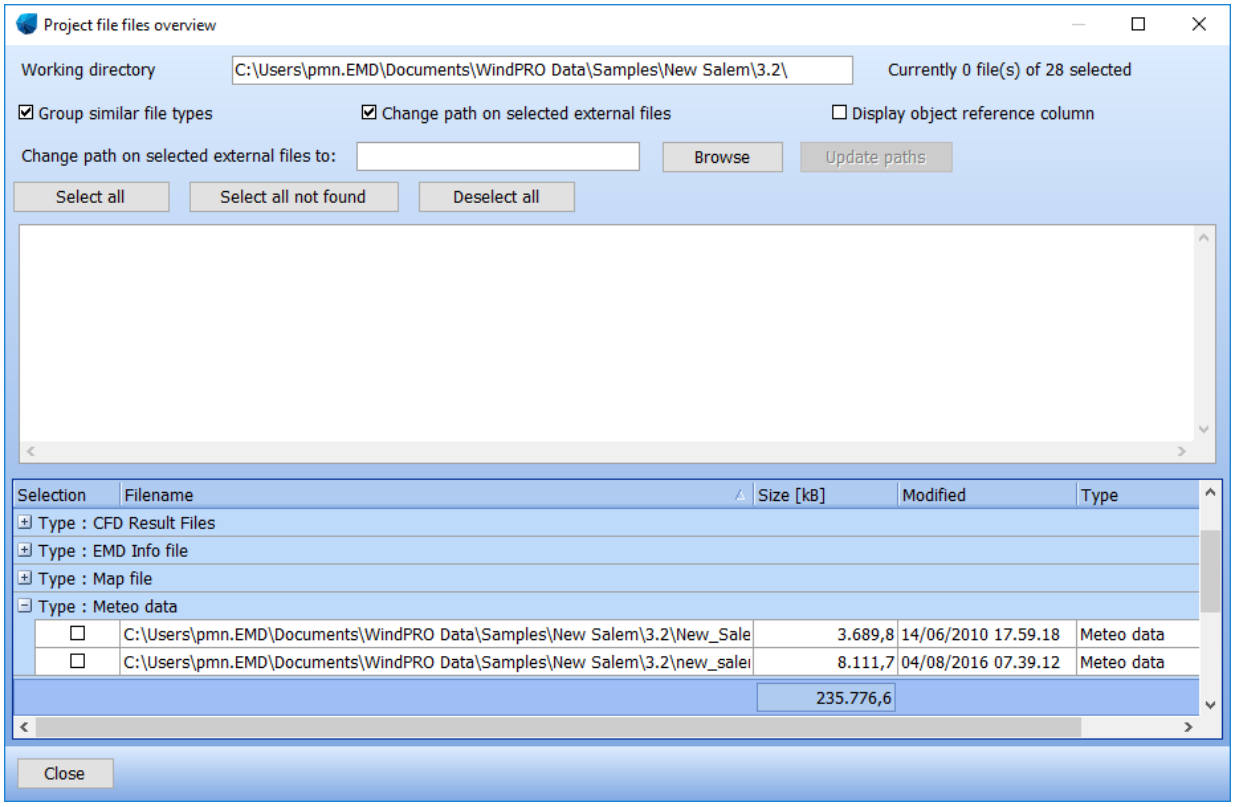
In the project menu, history shows different information of your project history.



This can be used to identify which changes/calculations you or another user made and when. You can see how many objects are in the project, where files are located, number of calculations etc.

2.3.1.2 Show all project files – relink files

In the project menu, **Show all files** leads to a tool where external files linked to the project can be relinked. This can be used if an extra hard drive for data is installed at your PC or projects are moved from server to PC or opposite. If you move by exporting (recommended), all files should be correctly relinked when importing. If your project is moved to another drive, then files that not are located in your project folder or below, will not be found. Then the relink feature is useful.

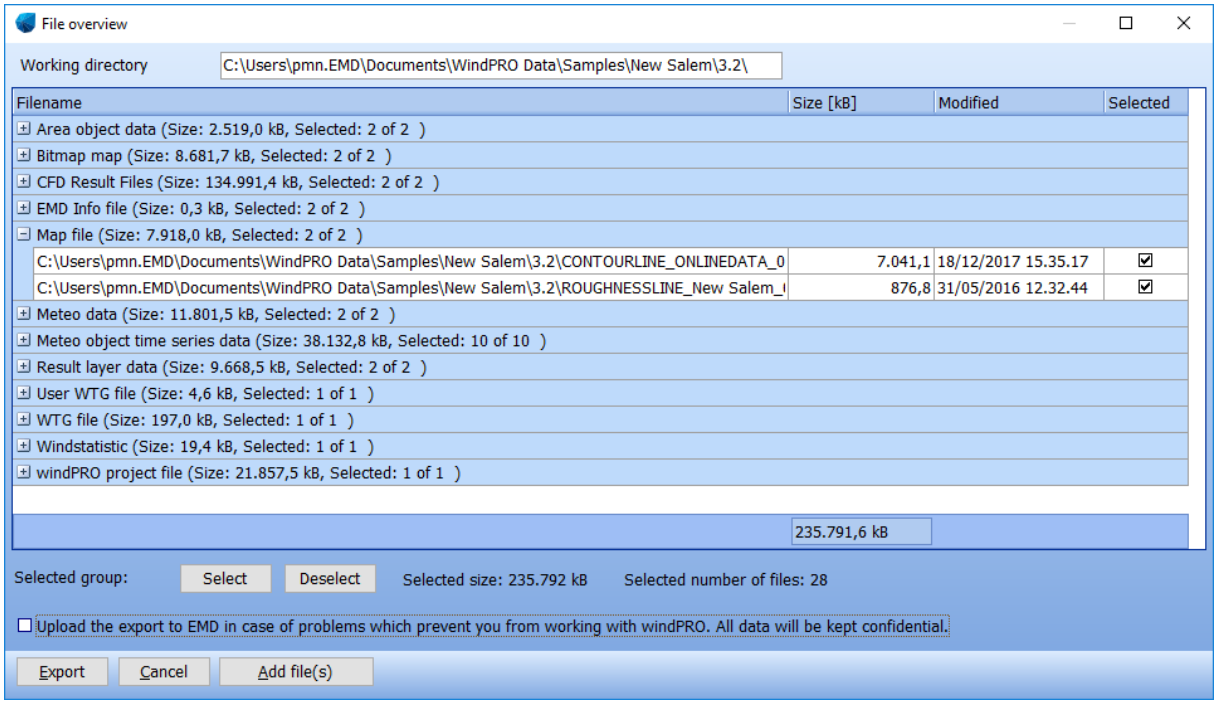


Files can be grouped by type and selected by group. After selection, browse for the new location and click **update paths**. Then the files are relinked and operational in the project.

2.3.1.3 Exporting windPRO project files

The Export function is used when you want to copy project information from one PC to another or create complete backup packages. A "normal" copy from Windows Explorer can be used, but then you

will have to make sure that all files needed by the receiver are included and that the files are placed in same folder structure. Otherwise, you have to re-link bitmap maps, Line Object files, etc.
With the Export function, you can let windPRO organize what should be included, and all data will be packed into one file ready to be opened from another windPRO application with updated links.



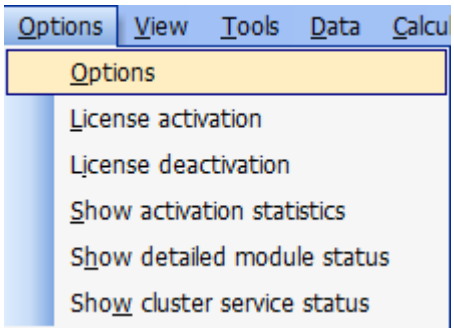
In the window shown above you can see how windPRO lists all relevant files for the export file. At this point, files can be deselected in order to reduce the export file size or to exclude information from the export file.

Simply expand the type of data and double-click on the file you want to select or deselect. Then click on **Export**.

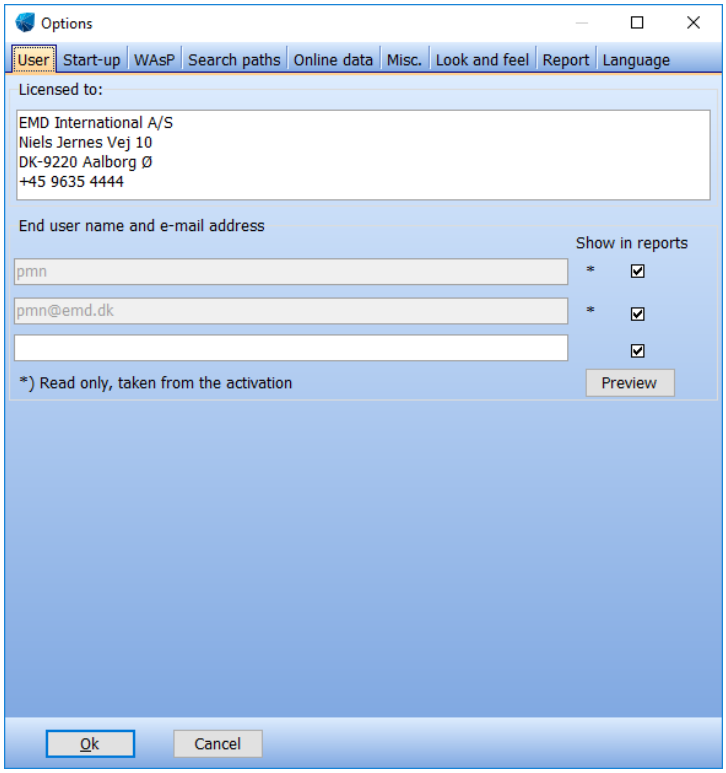
In addition to those files suggested by windPRO, you can also add files into the export from the **Add file(s)** button (before exporting).

For windPRO support, it is possible to upload the export to EMD (local agency) by checking the box at the bottom of the window. The export will be securely uploaded to EMD's server and an email will automatically be sent to the support agent. Any information deselected in the list is not uploaded.

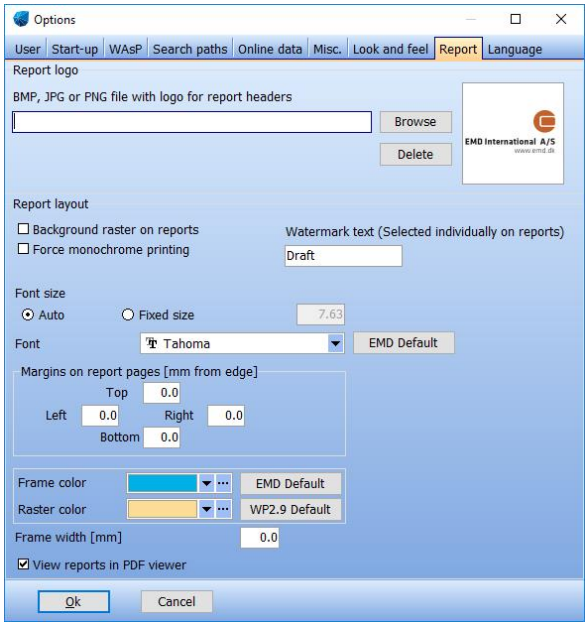
2.3.2 Options

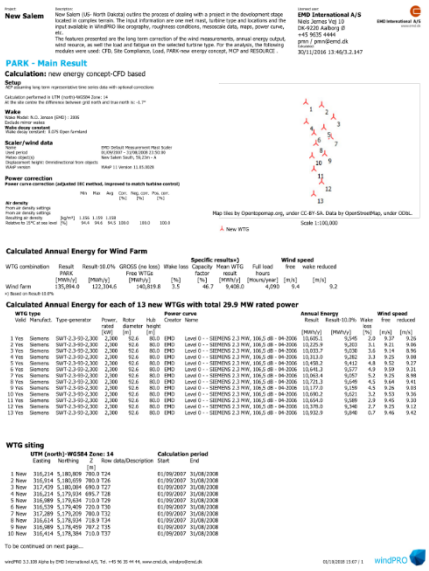


2.3.2.1 Options – User Reference in printouts

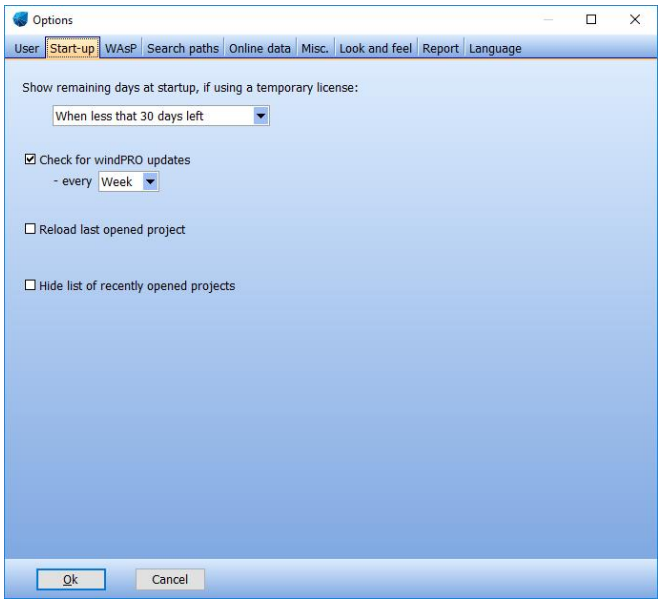


Here the name of the person and email address are from the activation (License) – it can be checked which lines shall be shown in reports. An additional line is available for department name, for example. Further settings of the report can be found under the Report tab. For instance, a company logo can be included which will appear on all reports in the top right corner. See Options – Report.



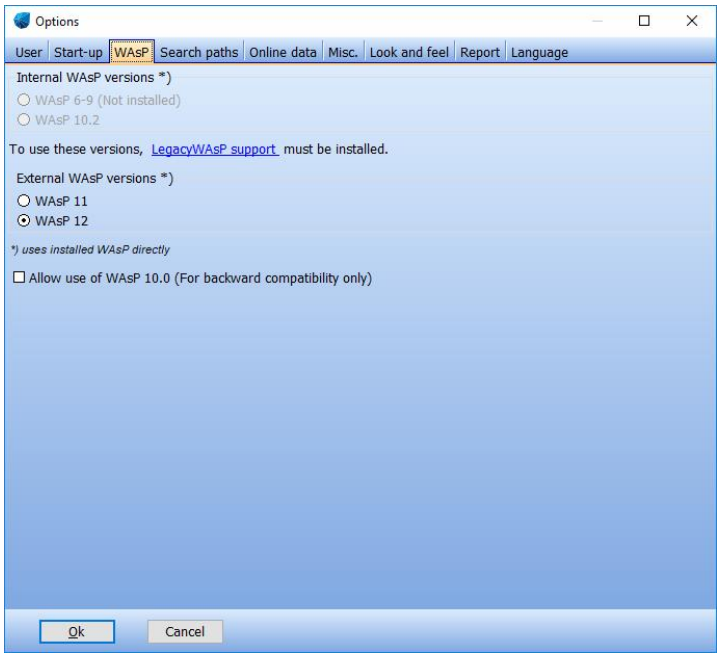


2.3.2.2 Options – Start-up



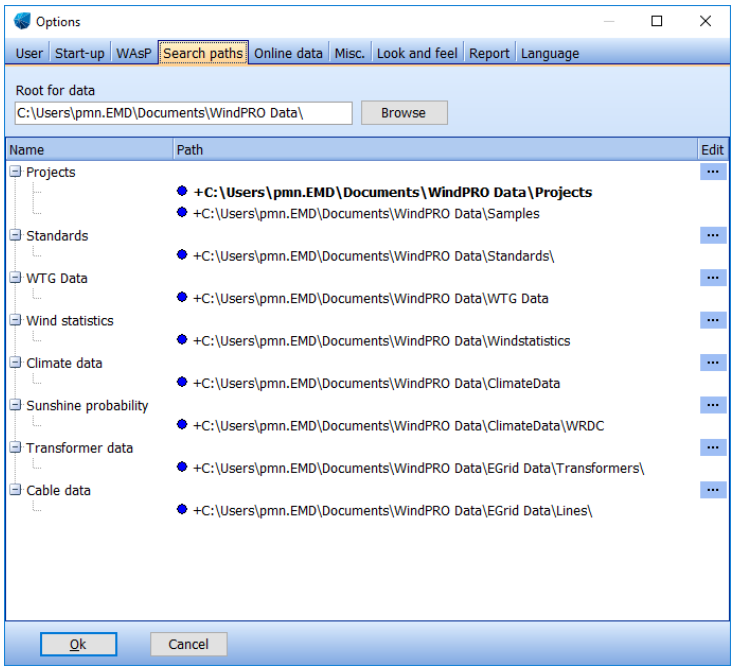
Start-up options are set from this window, such as the number of days left when using a time-limited license or the frequency of checks for windPRO updates. The last opened project can be set to be opened automatically when windPRO starts. The list of recently opened projects can be hidden from the list available under the menu Projects or from the starting screen (to protect confidentiality when displaying the starting screen, for instance).

2.3.2.3 WAsP Setup



If the WAsP program from Risø/DTU is used by one of the energy calculation modules, the version of the program must be chosen here.

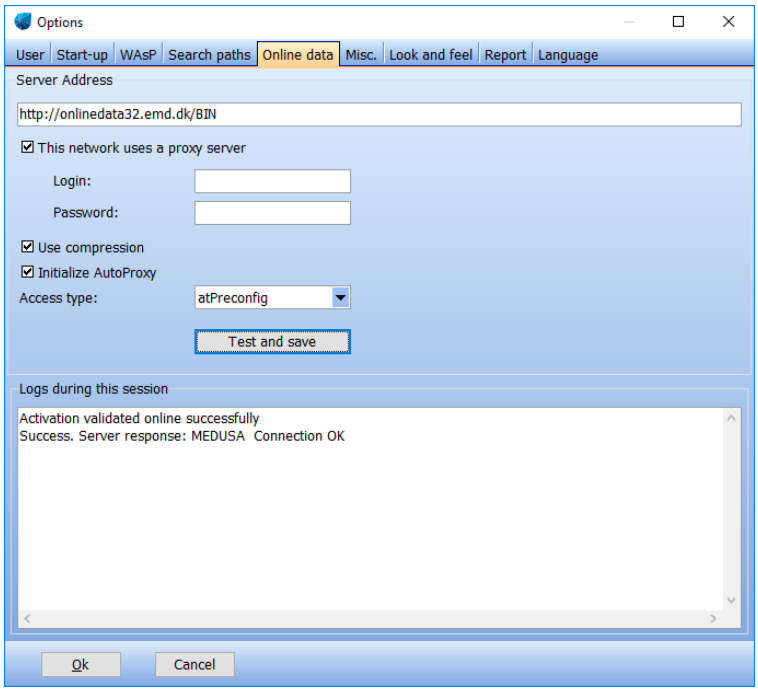
2.3.2.4 Options – Search Paths



The root for your windPRO data gives windPRO information on where the default file location is for storing new projects, and where to search for projects, data etc.

The Search path of the data used in windPRO can be changed from this Option. If a path becomes invalid, it will turn red in the list. The path can be edited by clicking on the three dots.

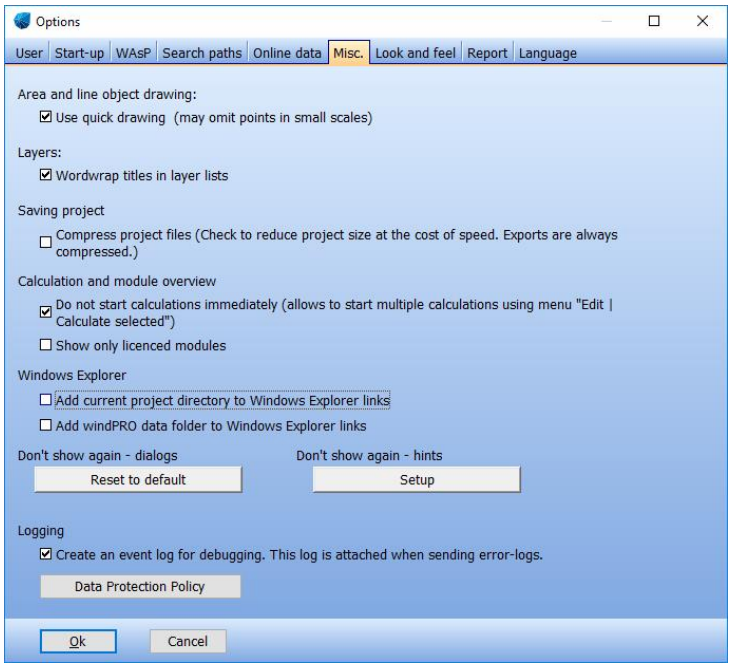
2.3.2.5 Options – Online data



The standard configuration to access EMD's server to download online data as shown above is valid for most users. However, if you are using a proxy with a password, these need to be entered here (please consult your network administrator). The remaining settings might need to be changed if the online data cannot be accessed. **Test and Save** button will tell if the connection to EMD's server can be established (internet connection is required). If the connection is not OK, try different combinations of the settings until Test and Save returns "connection OK" as shown above.

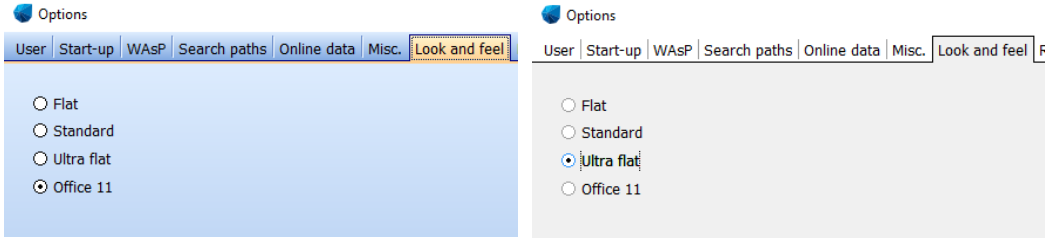
In some cases, it may be necessary to add the online data address to your firewall program to allow access. The online data address changes with each major update of windPRO, so it is always worth checking that all such addresses are included.

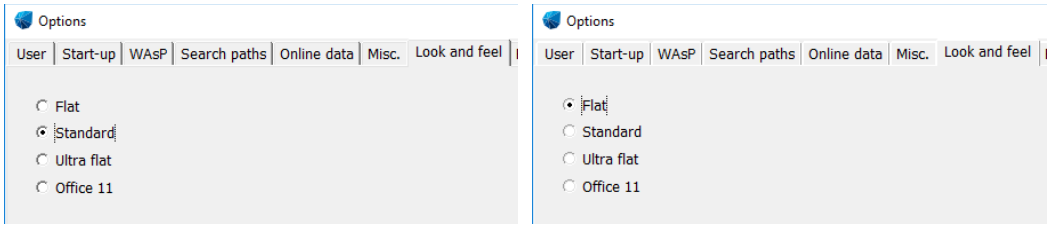
2.3.2.6 Options – Misc.



Many preferences can be defined here. Dismissed hints and dialogues throughout windPRO can be re-activated here.

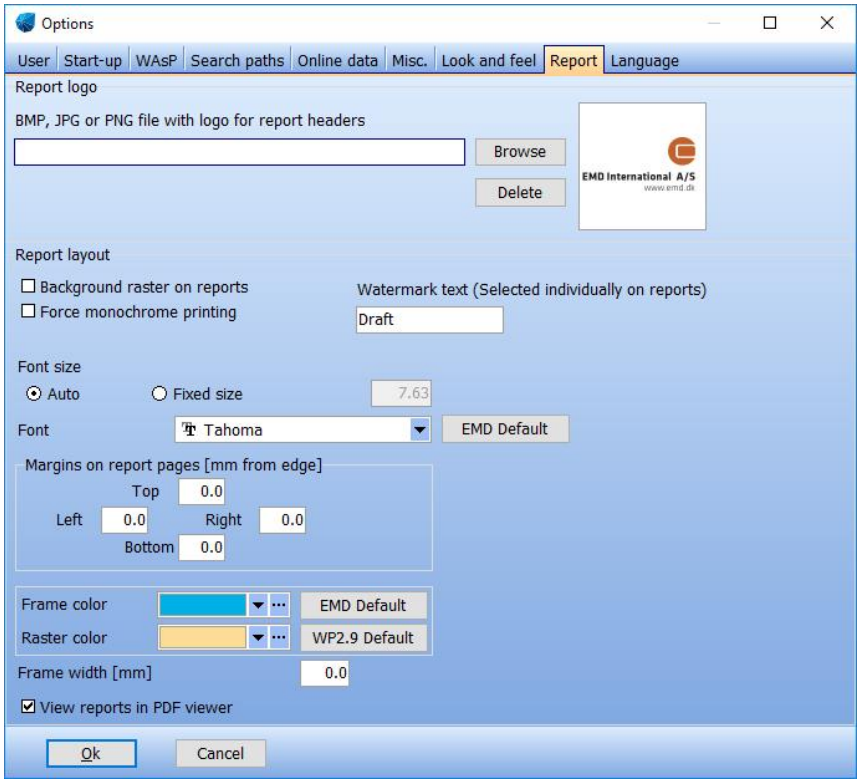
2.3.2.7 Options – Look and feel





This option changes the appearance/skin/theme of windPRO according to user's Windows setups.

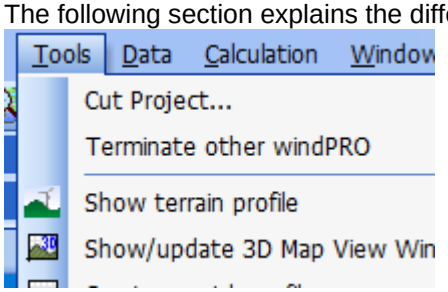
2.3.2.8 Options - Report



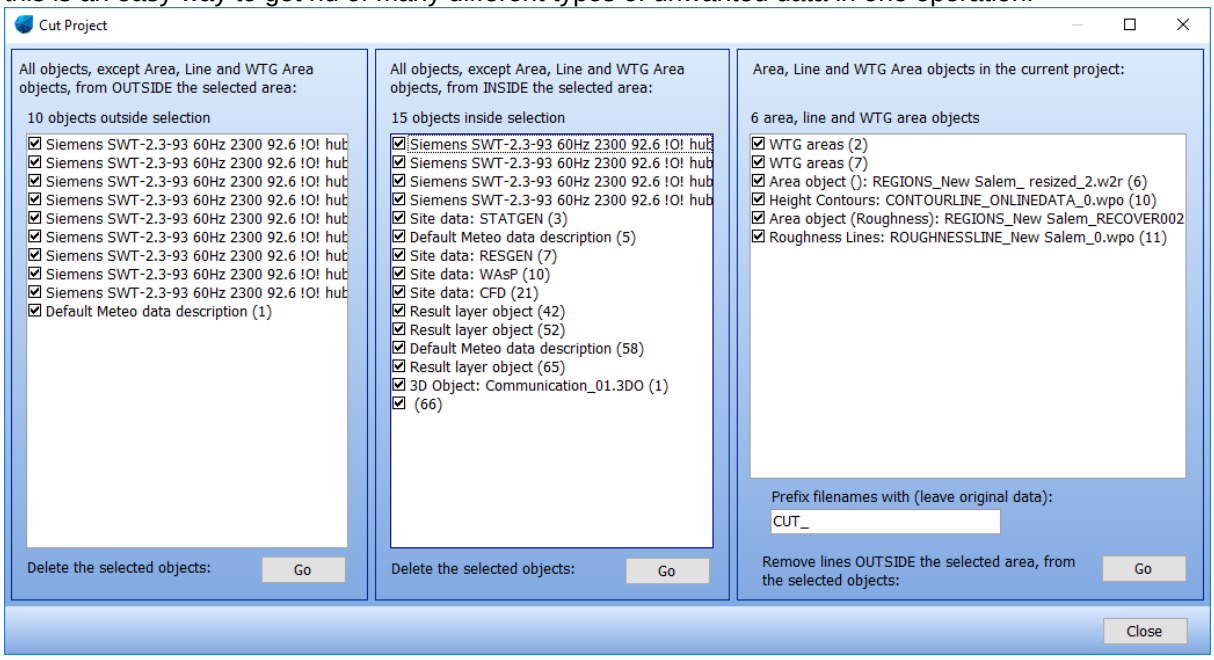
The last tab in Options is the Report tab. From here you can specify settings affecting all calculation reports. You can add your own logo to the report headers, add a watermark text, force monochrome printing, and specify the font size and type. The margins of the page can be set and the size and colors of the frame around the report can be changed.

2.3.3 Tools

The following section explains the different options in the Tools menu:



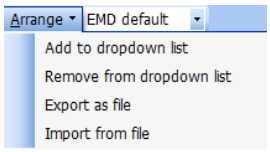
The **Cut project** tool makes it possible to delete all data inside or outside a given area. If you import a large amount of GIS data or height data from other sources and only wish to work on a limited part, this is an easy way to get rid of many different types of unwanted data in one operation.



- **Show terrain profile**: show the terrain profile created from the shape object. See Shape Object
- **Show/update 3D map view window**: Show the terrain in 3D. See 3D Map view
- **Create a quick profile**: select and show a predefined or created quick profile (from the ruler object). See Quick Profile based on Ruler object

- **Map Composer**: enable to setup maps for external use. See Map Composer
- **Import Streetview™** to PHOTOMONTAGE: See Chapter 7
- **Google Earth export**: export of the visible objects on the map to Google Earth (with the turbines in 3D). See Google Earth
- **Photomontage**: open an existing camera model/photomontage from this tool. See Chapter 7
- **Meteo analyzer**: to perform analysis on several Meteo objects. See Chapter 12.
- **Performance check**: Performance check is used to analyze the actual production of existing turbines against the calculated production. See Chapter 11.
- **eGrid table**: access or creation of the grid setup. See Chapter 9
- **Optimize**: starts the Optimize window. See Chapter 8.
- **Scaling setup**: See Chapter 3.
    - Season and day/night setup: Chapter 3.
    - Result to file export tool: Chapter 3.
    - Displacement height calculator setup: Chapter 3.

2.3.4 Arrange windows

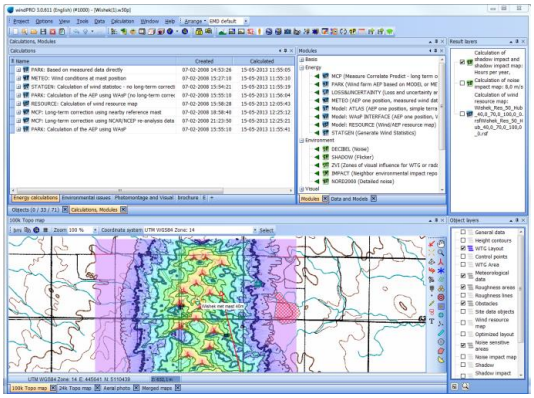


windPRO consists of several sub-windows which can be re-arranged.

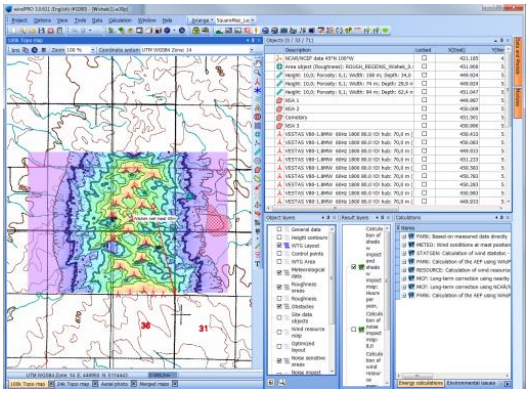
Add to dropdown list allows to keep the current user defined layout of sub-windows. This layout can be selected later on from the dropdown menu next to the Arrange tab.
Remove to dropdown list deletes the selected layout from the list.
Export as a file saves the layout as *.EMDlayout file so that it can be saved for a backup or shared between different users.
Import from file allows to use a given layout.

By default, the *EMD default* layout is selected in the dropdown list. Other layouts can be imported from windPRO data/ Standards using the Arrange menu. Some examples are shown below:

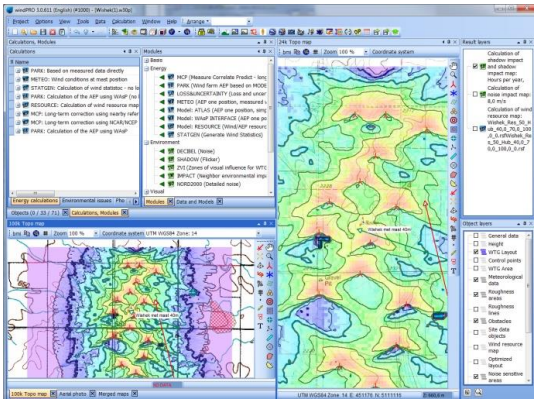
EMD default layout:



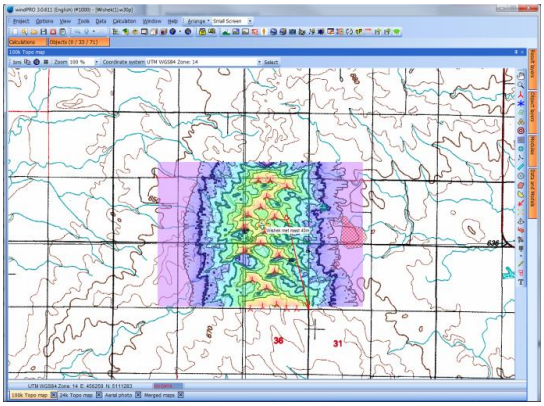
Square map laptop size layout:



Two maps layout:



Small screens layout:

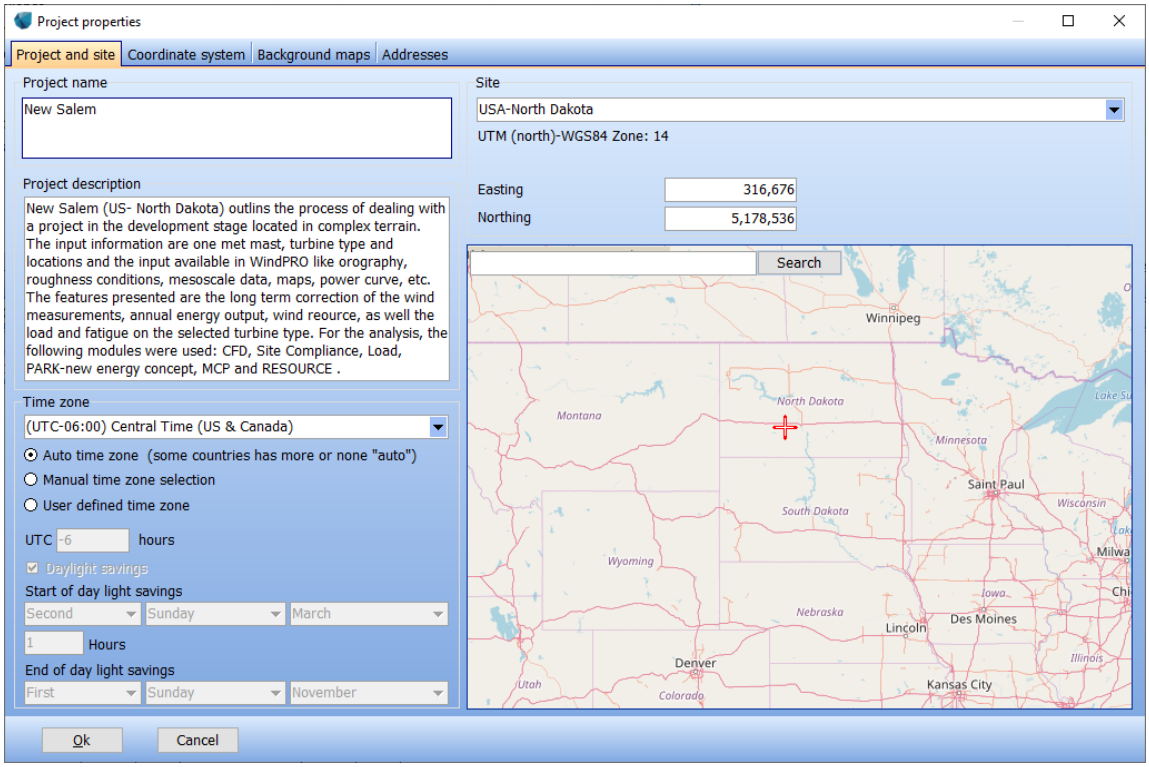


2.4 BASIS - Project Properties and Maps

2.4.1 Introduction to Project Properties (PP)

Project Properties covers all information regarding site description, coordinate system, maps and addresses.

If you select **Project Properties** from the **Project** menu, or if you click on the shortcut icon or create a new project, the window for input of project information will pop up:



2.4.2 Project Properties: Project and site

2.4.2.1 Project name and site description

A project name and a description of the project site and other information, which will appear on printouts, can be entered. Please note, that for each calculation performed, additional text relevant to the calculation can be entered. This means that the site description is the overall description of the site or general assumptions.

2.4.2.2 Site coordinates

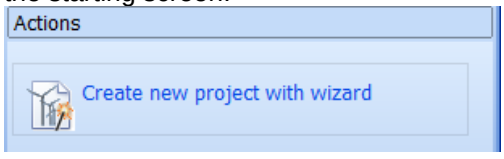
The preliminary site coordinates are entered here. If you have created a new project from the Project Explorer, site coordinates will already be filled in with approximate coordinates. The site coordinates (site center) will later appear on the map as a red crosshair and can be adjusted. The site center will be centered on the screen when opening maps later in the project design phase and is the default center of some calculations. If you are connected to Internet, Open Street Map maps will be available as background for fine tuning the position.

2.4.2.3 Time zone

Selecting the correct time zone is important in order to perform a correct shadow flicker calculation or photomontage. windPRO will aid you in the right choice showing major cities in the different time zones. For most locations, the time zone will be detected automatically based on site country. Where more time zones are used in a specific country, the manual selection will give you only the relevant ones. With user defined, all time zones are available.

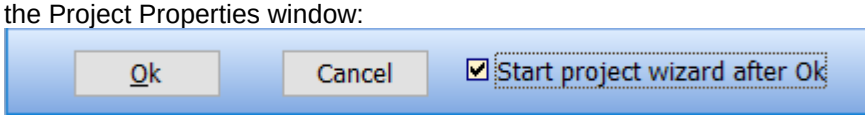
2.4.2.4 Project Wizard

A new project can be started with a wizard for easy download of online data. This can be done from the starting screen:

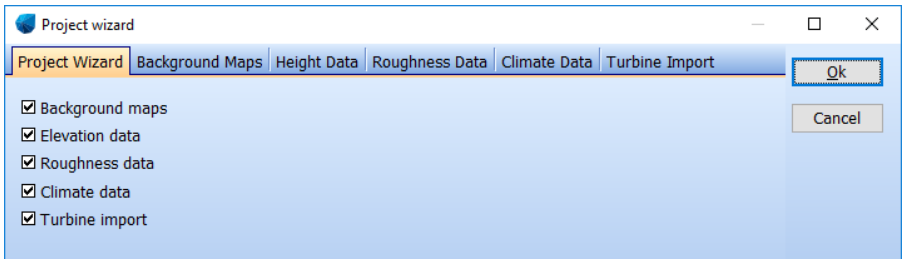


or from the top bar .

Alternatively, when creating a new project, a checkbox can be checked to start the project wizard in the Project Properties window:

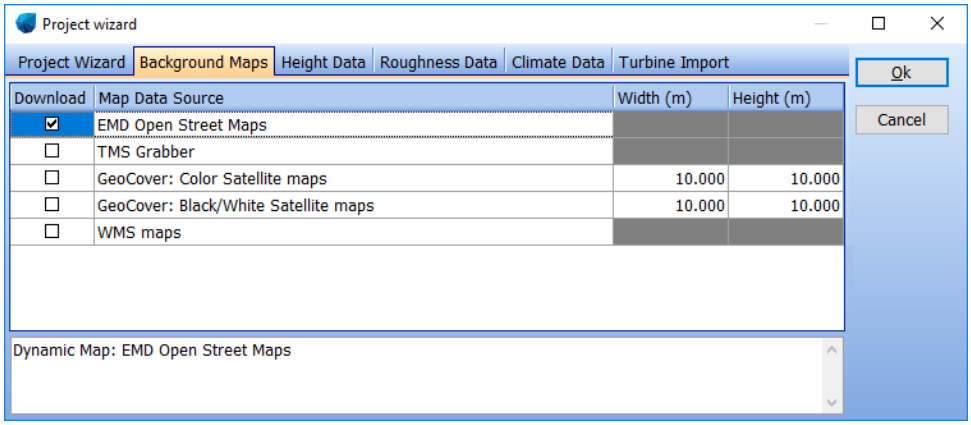


The types of data that can be selected are: background maps, height data, roughness data, climate data and existing turbine data. These data can also be downloaded individually from different part of the software. The project wizard downloads all at once, giving thus a better efficiency, easy access to the data (and a good coffee break, it can take some time depending on how many datasets you choose!).

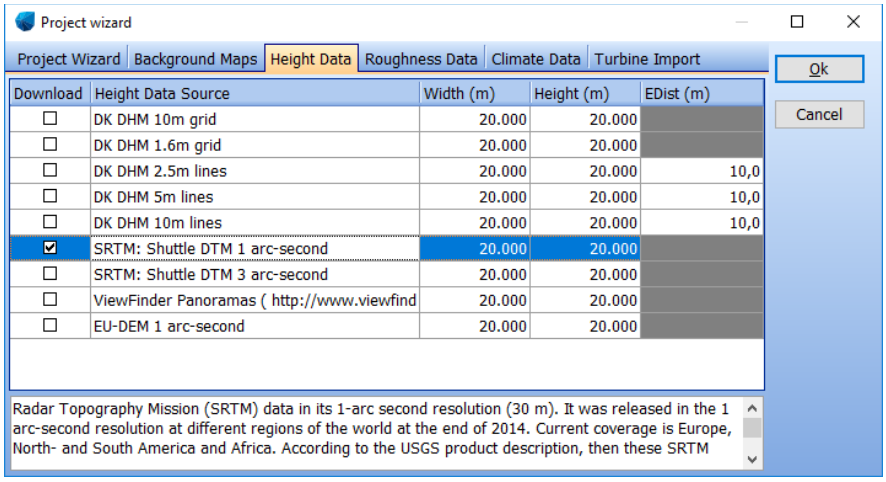


On the first tab of the project wizard, the type of data to include is selected. For each type of data, a source is selected in order to allow for a fast creation of project. In most cases though, the appropriate data should be selected on the different tabs. For all tabs, the amount of data to download (width and height of a selection rectangle) are given with the site center as reference. The description of the data can be read at the bottom of the window when selected with the mouse. The data to be downloaded is marked with the checked box on the left. Several data of the same type can be selected.

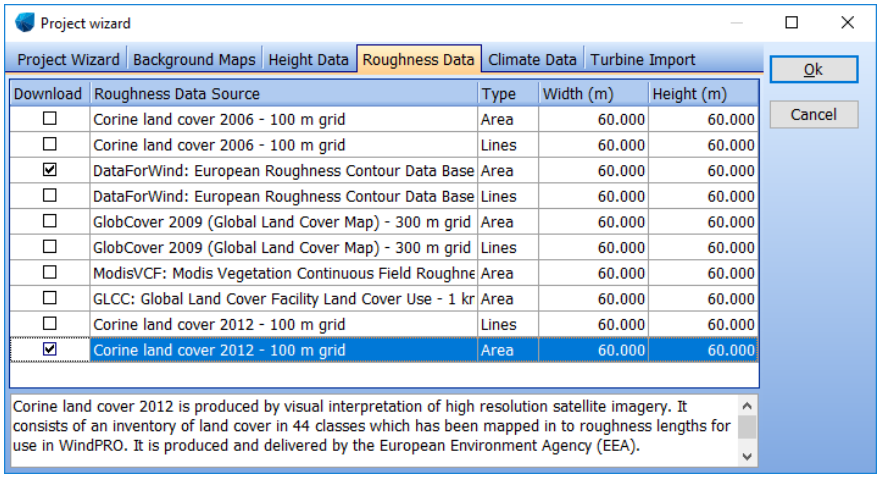
Please note that the data availability depends on the location of the project.



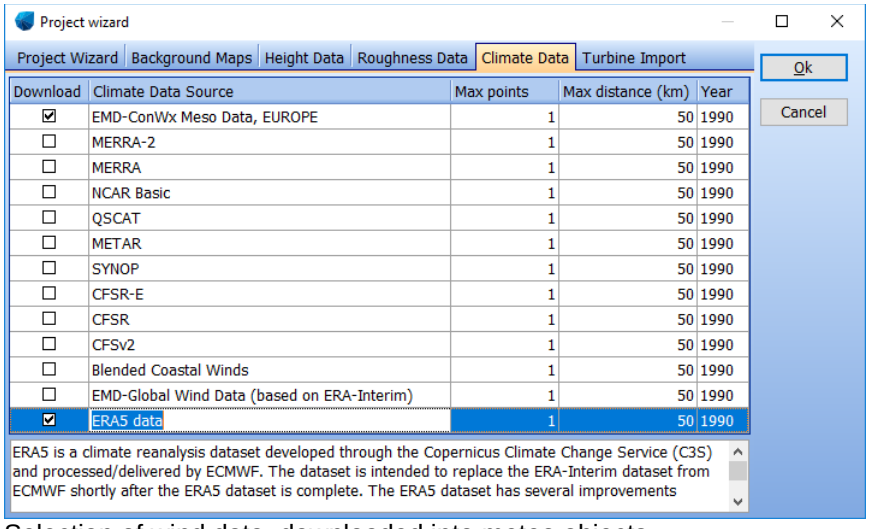
The resolution of the maps and other details (for WMS maps) are defined once the OK is hit and the downloading starts.



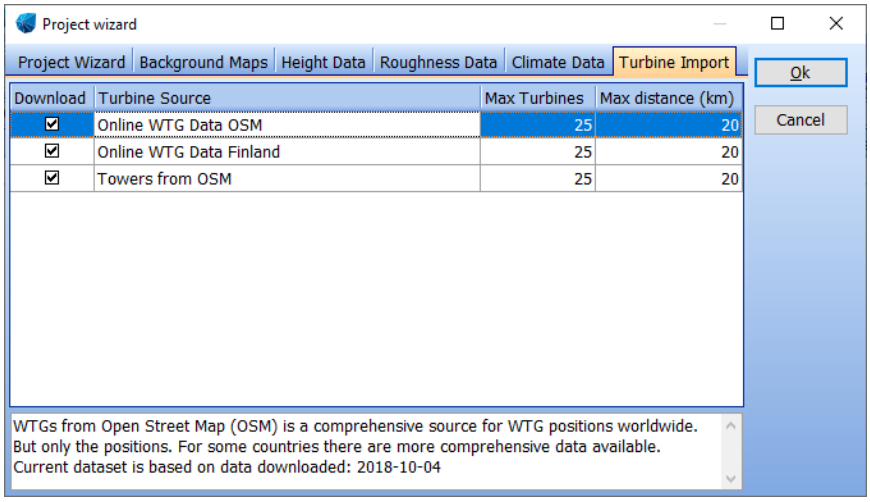
Selection of height data, downloaded in a line or grid object.



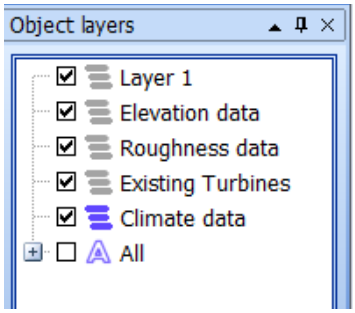
Selection of roughness data, downloaded in a line or area object. The area object is recommended though, as it allows for easier editing.



Selection of wind data, downloaded into meteo objects.



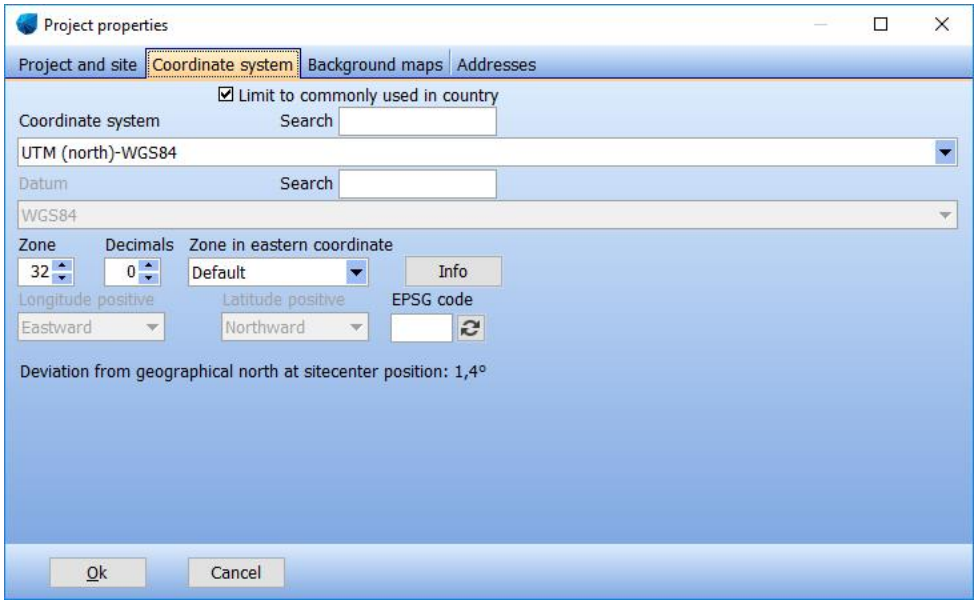
Selection of the existing turbines or towers (max number and distance to the site center)



All downloaded data are sorted in a specific layer (see layer structure).

2.4.3 Project Properties: Coordinate System

On this page you can select which coordinate system you wish to work with. If you have created a new project from the Project Explorer, a default coordinate system and zone will automatically be provided, based on the country and the location. It's important that you select the system which matches the scanned maps or object coordinates you will be using. Note: WAsP is not able to work with latitude/longitude, so you may need to choose a more appropriate system. If not, windPRO will automatically convert data to WGS84 when running WAsP.



On standard maps (paper) the coordinate system used is printed somewhere on the map itself. Almost all maps will contain a latitude-longitude (lat/long) grid. Therefore, this system can always be used. However, the system (degrees, minutes and seconds) is inconvenient to work with and makes measurements, conversions, checks, etc. a tiresome task. If the information is also available in an orthogonal (easting-northing) system, this system should be used.

Number of decimals on coordinates can be chosen to be 0, 1 or 2.

The coordinate systems shown can be filtered, so only the most relevant ones for the project country are shown.

The coordinate system engine is updated for every new windPRO version. Most often the updates are unnoticeable. However, with the change to 64-bit in windPRO 3.4, all projects created prior to windPRO 3.1 SP1 will automatically be converted to use a newer 64-bit compliant coordinate system engine. This may cause a change of object positions of less than 100 cm.

The EPSG code is referring to the coordinate reference systems and coordinate transformations, which may be global, regional, national or local in application made by the IOGP (International Association of Oil & Gas producers).

2.4.3.1 The UTM System

The UTM system is used worldwide, and is often printed on the map material.

The earth is divided into 60 zones as defined in the figures below. Each UTM zone has a longitudinal width of 6 degrees. The median line of a 6 degree section has, by definition, the value of 500,000 meters. The widest part of a section (approximately 667 000 m) is at the Equator, (the Earth's circumference of ~40,000,000 m / 60 sections). The x-coordinate value (Easting) thus lies between 167,000 and 834,000 meters, and is always positive.

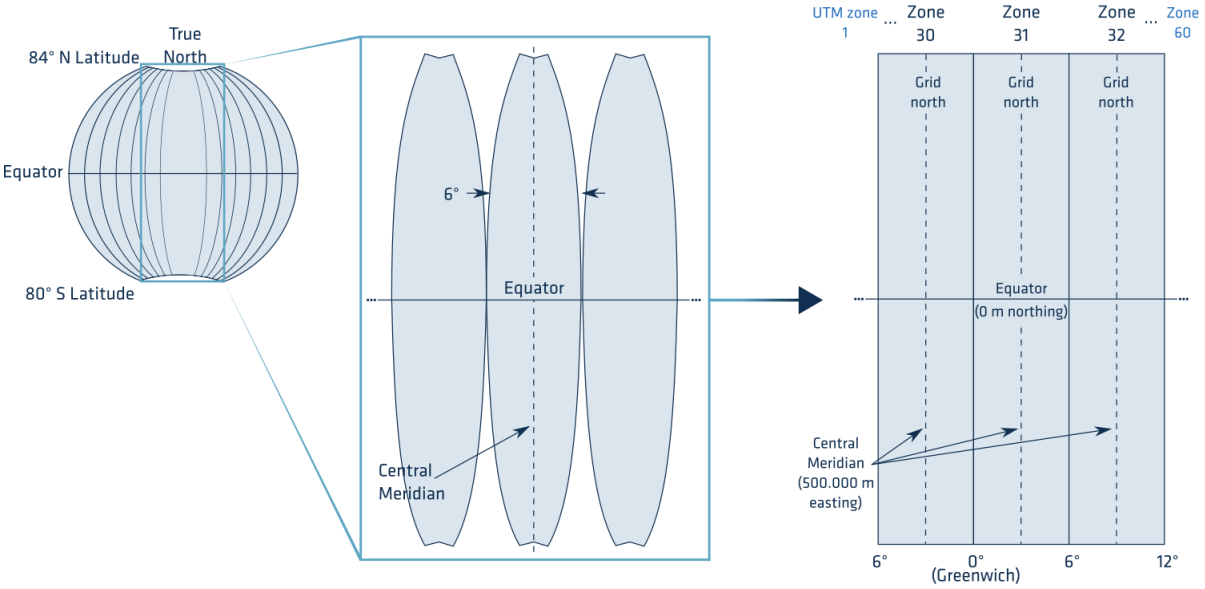
In the northern hemisphere, the y-coordinate (Northing) equals the distance to the Equator. In the southern hemisphere, the y-coordinate equals 20,000,000 meters minus the distance to the Equator. This means that 1 km south of equator, the y-coordinate is 19,999,000.

The UTM South system is used more commonly, where the y-coordinate is 10,000,000 minus the distance to the Equator. In this case, 1 km south of the Equator, the y-coordinate is 9,999,000.

The datum of the UTM system indicates how much the globe differs from being exactly round (the datum refers to the set of "unfolding" algorithms used to change the curved surface of the globe into a flat map, often referred to as the Ellipsoid). Several different datums are used in different parts of the world, but more and more countries are changing to the WGS 84 also named ETRS89 in the EU.

Longitudes and UTM zones

	UTM zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Western longitude (west of Greenwich)	From	180	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6
	To	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0
	UTM zone	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Eastern longitude (East of Greenwich)	From	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	156	162	168	174
	To	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	156	162	168	174	180



Common datums used with UTM coordinate system:

- WGS 84 = World Geographic System, the world standard since 1984. Similar to EUREF89.
- ED 50 = European Datum since 1950 = Hayfort
- NAD = North American Datum (More variants)
- SAD = South American Datum

2.4.3.2 Other metric systems

Many countries have also defined their own systems, which are commonly used instead of the UTM system. In Denmark, the System 34 is used. In Germany it's the Gauss Krüger system, and in Great Britain it's the British National Grid that is used. The list of which coordinate systems windPRO recognizes will be updated continuously.

The British National Grid calculates with two different Ellipsoids (Datums); the AIRY and the GRS80. The British Ordinance Survey has informed us that all British maps use the AIRY Ellipsoid. The British National Grid has its origin at Lat. 49 N and Long. 2 W.

If the system you are currently working with is not included in the windPRO list, you can define your own local system, and indicate (0,0) as the bottom left corner of the project area.

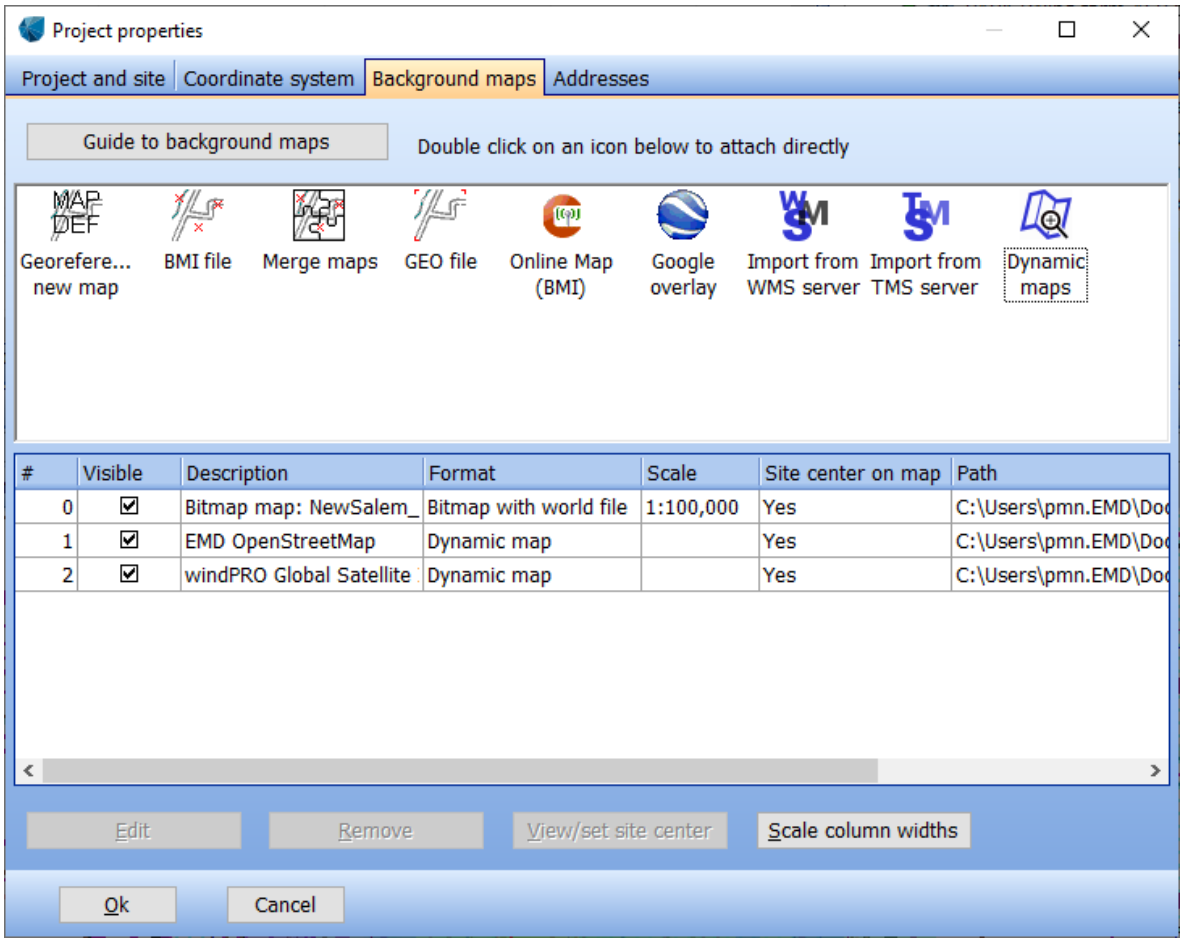
If the "Local System" is selected, you have to enter 1-3 reference points for the local system, in a coordinate system which is recognized by windPRO in order for it to be able to calculate the exact geographic position. Several of the calculation modules and most printouts use the geographic position. Lastly, you can enter deviation data if the system used calculates with an angular deviation to geographic (true) north. This deviation is often indicated on the map material (if only at one fixed point).

One of the advantages of using a local system is that you can work with small coordinate values instead of the 6 and 7 digit coordinate values used by other systems. Another advantage is that you can continue to work with client information when you receive information from a client in his local system which he would like to see applied, e.g. in layouts.

Please note that your choice of coordinate system determines the system in which you can enter coordinate information. However, you can always change the system during your work and let windPRO handle the conversion. Coordinates already entered will automatically be converted to the new system, as all coordinates are stored internally as latitude/longitude degree values. This means, that you can enter different information in different coordinate systems, e.g. wind turbine positions in the UTM system from GPS measurements and information from local authorities regarding existing populated areas (for noise calculation) in the latitude/longitude system.

2.4.4 Project Properties: Background maps

In the Tab Sheet **Background maps**, link to maps can be entered.



The map with # 0, will be the default map in reports. Drag and drop to reorder the list.

There are multiple ways to attach background maps:

- Use MAPDEF for defining scanned maps from scratch or for stitching additional maps that already contain coordinate information (GEO Tiff maps).

- BMI files (windPRO's internal background map format), that holds information on geo-referencing and coordinate system.
- Merge maps is a function where you can open a number of .bmi files and the software will automatically merge these into one map in the screen view. Note: all maps must have same resolution (pixels/m).
- GEO refers to geo-referenced "world file format" which is two files, an image file and a coordinate specification file, like *.bmp and *.bpw, *.jpg and *.jgw files or *.tif and *.tfw files can be attached just by pointing out the location of the formatted map file(s).
- Online maps gives the user access to download background maps from EMD servers with a specific size.
- Google overlay enables you to import an image/map calibrated in Google Earth as an overlay.
- WMS (Web Map Service) and TMS (Tile Map Service), are standard protocols for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database. windPRO comes pre-loaded with a range of WMS and TMS servers, and you can add WMS and TMS servers to the list. These servers may include free and paid for sources of map data.
- Dynamic maps are global background maps which are automatically downloaded as you zoom and pan around the map window. Multiple datasets are available such as, satellite imagery, topographic maps and Open Street Maps. Datasets are updated continuously.

2.4.4.1 Relevant background maps

As previously mentioned, maps make the project design work much easier. The maps used in windPRO are primarily bitmap background maps, which show populated areas, roads, forests and other objects that you need to take into consideration when planning the project layout. Digital orography maps (Height Contour Lines) or roughness maps are described in section 2.8, Line Object.

Many maps can be downloaded directly within windPRO from EMD's servers at the desired scale and already georeferenced.

You choose the maps according to your kind of work. As a guideline, the following map scales are recommended:

1:10,000 For very accurate positioning of turbines and measuring distances for noise calculations. Possibly with landowner boundaries for planning consent work

1:25,000 Normal scale for positioning of turbines, definition of local obstacles, input of orography, measuring distances for noise calculations and entering check points for visualization.

1:50,000 Suitable for roughness classification within the nearest 5-10 km of the site.

1:100,000 Used for roughness classification between 10-20 km from the site.

If you scan the maps yourself, a combination of 1:25,000 and 1:100,000 will probably be a reasonable compromise between time consumption and usefulness. High quality aerial photos are also very useful to locate important obstacles, dwellings, forest, existing turbines…

The link to the maps function is an option - not a requirement for carrying out calculations under windPRO. However, this option should be used whenever possible.

2.4.4.2 IT maps

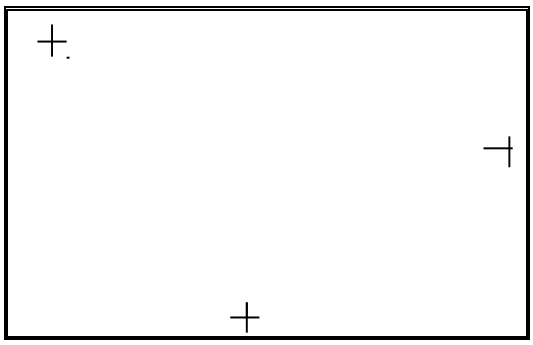
This import options has been discontinued since windPRO 3.4.
This import option allowed loading of old maps in IT format from the Danish Kort- og Matrikelstyrelsen (the Danish Ordinance Survey). The new version of maps for Denmark is available for free as WMS maps and as Dynamic maps.

2.4.4.3 Calibration of bitmap maps with MAPDEF

Bitmap files can be scanned or digital images of maps, where you subsequently have to make a coordinate calibration. MAPDEF is used for the Geo TIFF maps, where the TFW file holds the coordinate information. It is also used for stitching additional maps together, rotating, cutting etc. Double-click on the icon MAPDEF in order to start processing one or more new maps for the project.

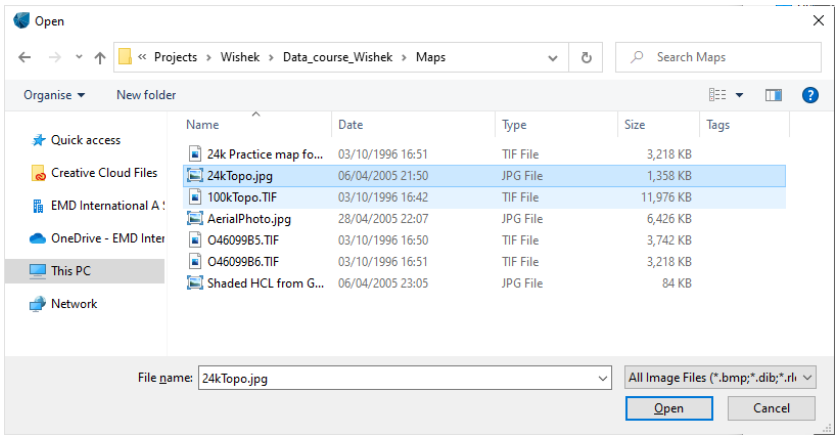
Using a bitmap image without coordinate information:

1 Scan the required map sections to a file on your computer.
2 Select the bitmap map containing the map sections.
3 Rotate the map so that it's aligned with north (pointing up).
4 Mark three points and enter their coordinates. An example of positioning of the points you use for the calibration of a bitmap to a .BMI file is shown on the below sketch.

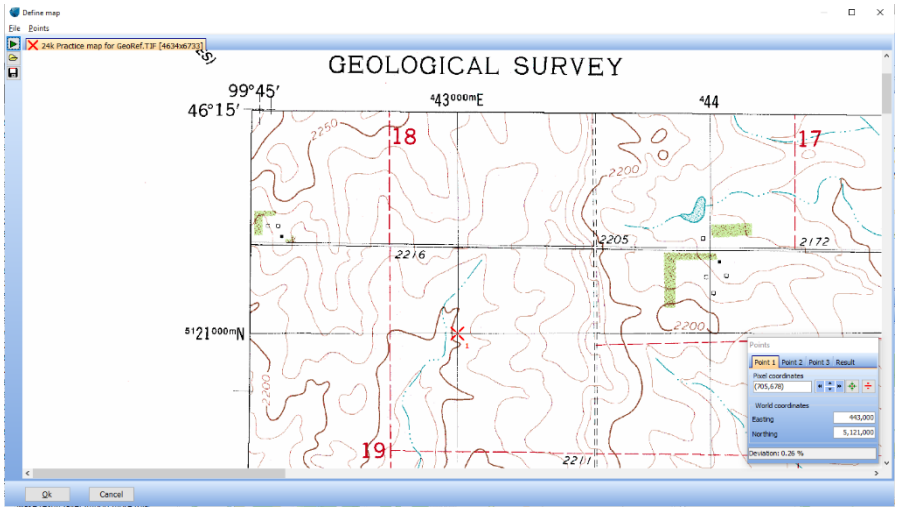


5 Repeat the above four steps until three coordinates have been defined for each map section.
6 Orient the maps so they are correctly rotated for merging (combining the maps).
7 If necessary, cut the edges of the map sections. Note map 1 (first attached) is at the bottom, which means that no cutting is needed for this one.
8 Save the .BMI map.

The preferred bitmap format is .PCX, although most other formats will also work. Make sure to include the edges of the maps in the scanning process, as they usually hold the grid coordinates. **Please notice that the user has the full responsibility of not violating any copyrights.** Save the maps in folders that you use for this purpose only, or in the windPRO project folder with the local project.

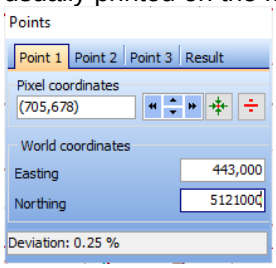


When **MAPDEF** is opened, you have to select which map file(s) to add (more than one map can be added at a time). The file browser is used for this.



Once the first map segment has been scanned, the map is aligned with north.

The positions are marked by clicking on the positions on the map where coordinates can be read or obtained. Make sure to place the three defining coordinate sets as far away from each other as possible in order to be able to maximize the accuracy of the definition. When you mark the first point, you have to tell the program which coordinate system you are going to use. The coordinate system is usually printed on the map.



The four arrows indicate a fine adjustment of the pixel coordinates if for example. an intersection between two gridlines has not been selected precisely enough.

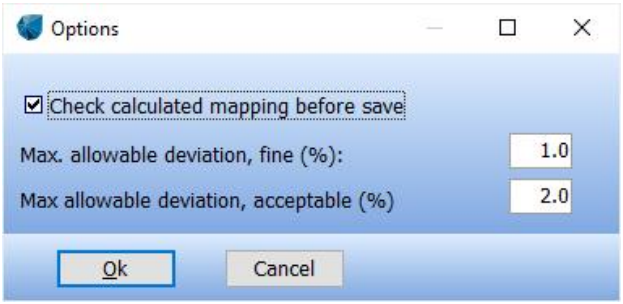
The menu for entering positions enables you to center the map around the actual point (or to get it inside the area which is rendered on the screen).

If a position is incorrect (or too poorly positioned) it can be deleted.

The last Tab Sheet to the right in the menu box for entering positions is **Result**. This window indicates the correlation between the entered coordinates and the pixel coordinates. One position is calculated based on the two other positions and the deviation is checked. The deviation is categorized into:

- Fine (default deviation less than 1%)
- Not precise, but acceptable (default deviation 1-2%)
- Not acceptable (default deviation more than 2%)

The third category result indicates that you have to look for possible errors or redo the definition as such a level will not allow the map to be saved. Note: The levels of acceptance can be defined manually in the **Points** | **Options** menu.



You add more maps by clicking on the green arrow in the upper left corner of the window (repeat the previous actions 1-4). Please note that this menu item is used to add maps that are to be merged to the previous map(s). Different map scales or map types are created as new maps.

You save the map by clicking on the **OK** button. When you save the map it's added to the list of maps that windPRO can use in the actual project. The map is saved as a .BMI file which holds the coordinate information and file names for the new adjusted graphic files which are saved as .PCX files designated as .B0, .B1, .B2, etc. At this point, the original graphic files can be deleted to save disk space.

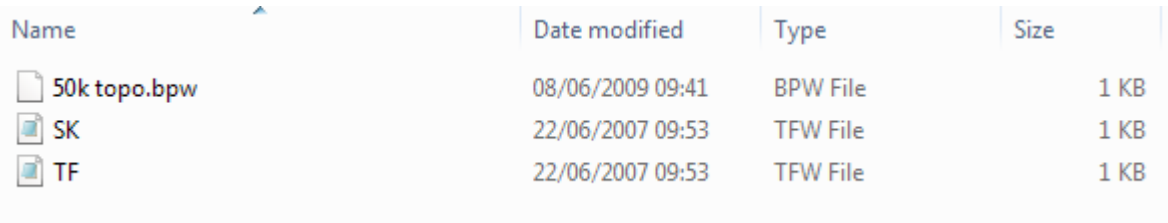
Once the .BMI file has been defined and linked to the project, you can define the site center coordinates on the map (See View/set site center).

Apart from the main items described here, a range of other functions are available, e.g. adjustment of brightness and colors

2.4.4.4 GEO “world file” maps.

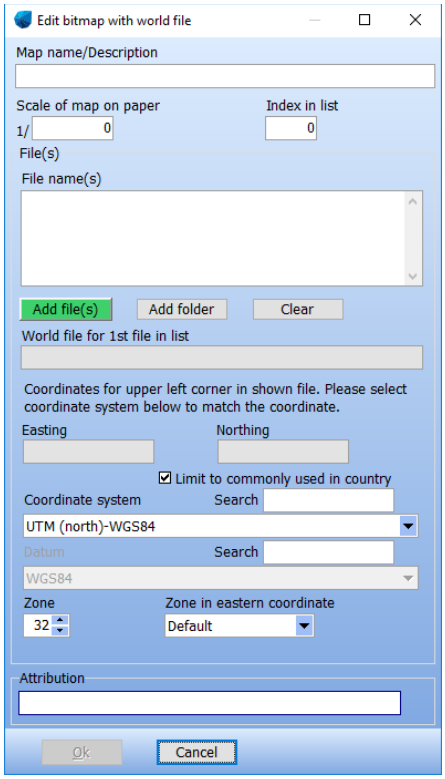
GEO file

Double-click on GEO file to add one or more georeferenced world files that can be .JPG and .JGW files, .BMP and .BPW files or .TIF and TFW files. Click Add Files and simply select the file(s) in the list. Only the world files (.JGW, .BPW or .TFW) files will be shown in the browser by default.



Name	Date modified	Type	Size
50k topo.bpw	08/06/2009 09:41	BPW File	1 KB
SK	22/06/2007 09:53	TFW File	1 KB
TF	22/06/2007 09:53	TFW File	1 KB

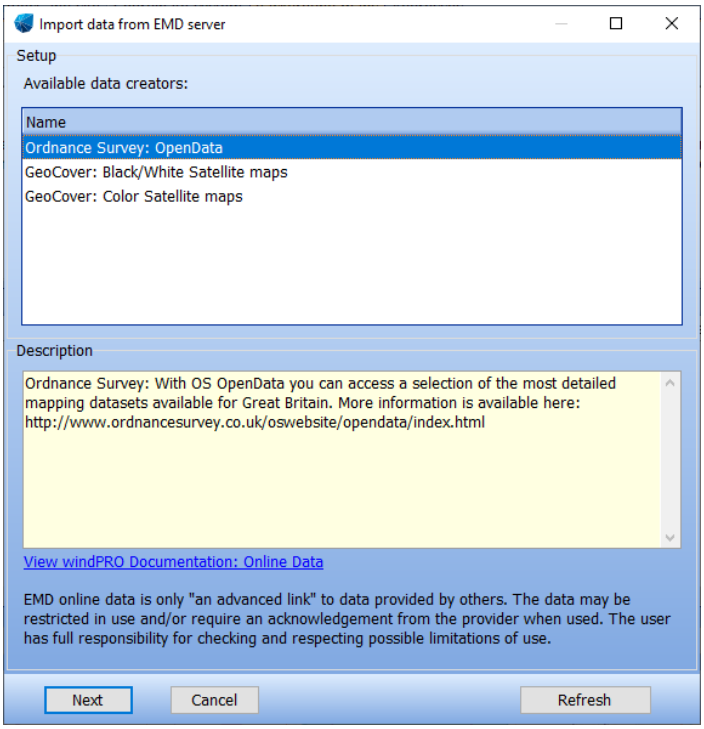
A small .TFW file holding the coordinate information must be available together with the main .TIF file holding the bitmap. windPRO performs geo-referencing based on the .TFW file and the number of horizontal and vertical pixels in the .TIF file (so do not change the pixel size of the .TIF file without changing the info in the .TFW file!). However, it can be a good solution to change both the .TIF file and the .TFW file if the .TIF file is very large and far too detailed). Make sure that the .TFW file is stored in same folder as the .TIF file and has the same name. Please notice that the .TFW file does not hold any information on coordinate system or datum. This must be known and given as input.



Add folder is used when you have a region or a large area covered by several georeferenced world files. By linking to the folder where the files are, windPRO will find and show the relevant background map in Maps and Objects window. This is convenient in the case of a large number of files without knowing exactly which files are relevant for the project. This option is for example useful for projects in Denmark, where Georeferenced world file maps can be downloaded for free for the whole country and at different scales from www.kortforsyningen.dk . When Add folder is used it is important that the files in the same folder have the same scale and are of the same type.

2.4.4.5 EMD Online maps

Online maps give the user access to download background maps from EMD server. It will automatically be detected which map sources are available for the site location. EMD will develop the service continuously and add more sources.



The online service detects which maps are available around the location of the specified project site.

For the GeoCover maps, after selecting the source, you can specify width and height of map. The resolution will typically be automatically set to give a reasonably small file size that can be downloaded immediately. For some data sources you can choose the resolution.

For other map sources, you will be presented with a screen grab window in which you can usually zoom in or out to select your chosen map area. Clicking “Save as BMI” will save the map.

The Online map is added to the list as .BMI files, the internal windPRO background map format.

2.4.4.6 Google overlay

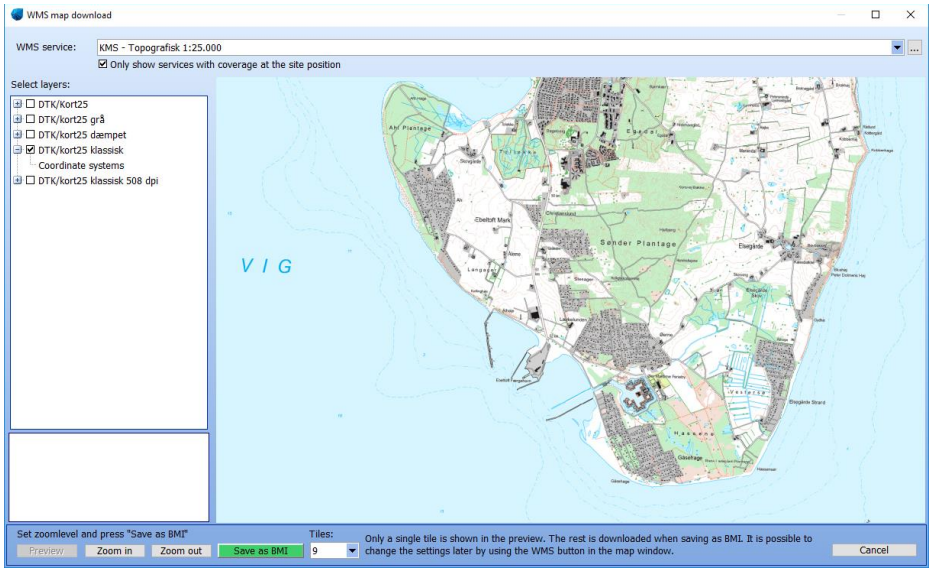
Google Overlay is used to import maps calibrated in Google Earth (this should not be confused with directly importing Google Earth images). In Google Earth, it is possible to add a bitmap as an overlay using this icon in the top bar. The bitmap can then be stretched, rotated and moved in order to fit with the background of Google Earth. It might be useful to change the opacity to get a good match between the whole image and Google Earth. The view in Google Earth shall also be vertical to the map to avoid any distortion. Once the calibration of the image is done, right click on its layer and select Save as to save the overlay as a kmz file. This file can finally be loaded in windPRO as a background map with the Google Overlay import.

2.4.4.7 WMS

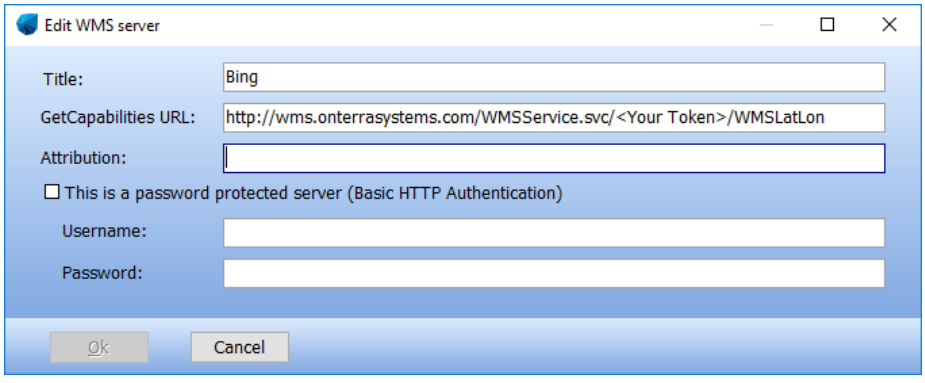
A Web Map Service (WMS) is a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database. windPRO has setup some WMS servers, but users can add WMS servers to the list. The WMS maps is saved in BMI format

Select the WMS service from the dropdown menu at the top and then the relevant layers of available data. Click on **Preview**. One tile centered on the site center is downloaded and shown. The resolution of the map is adjusted with the zoom. The more zoom the higher the resolution is. The size of the map is defined by the number of tiles to be downloaded.

Some maps are available in different coordinate systems, which can be changed by expanding the tree structure of layers on the left hand side in the image below.



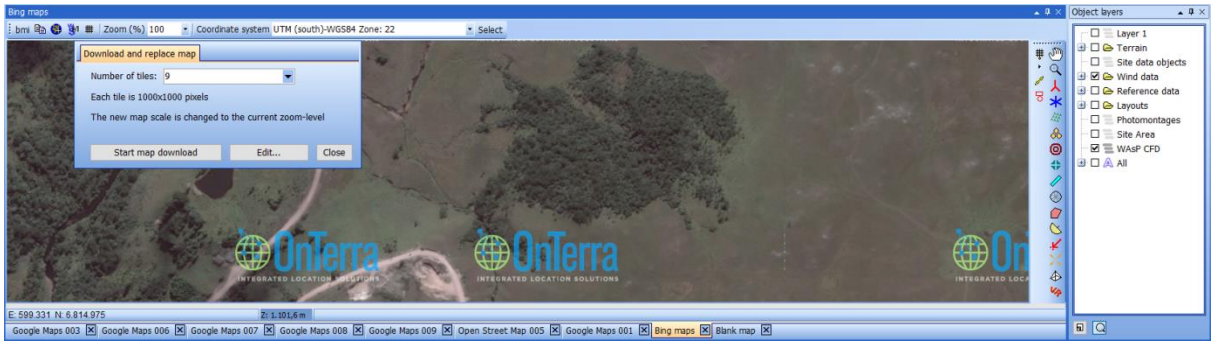
It is possible to add WMS servers to the list by clicking on the three dots to the right and then on Add. This way, you can get access to aerial satellite maps from Bing, custom OSM maps etc. However, most WMS providers (e.g. onTerra Systems) require a unique token in exchange for a paid subscription.



The GetCapabilities URL has to be obtained from your WMS provider. If the WMS server is password protected through basic HTTP authentication, you can input your username and password.
When the resolution and number of Tiles is decided, click on **Save as bmi** to download all the tiles and get a new map in the list of the background maps. Note that the number of tiles and the resolution

can be adjusted later on, from the WMS icon on the map window. The map files are saved at \windPRO Data\Samples\[Project]\maps.

If the WMS-server is password protected through basic HTTP authentication, it can be accessed by ticking the password checkbox and inputting your credentials to the WMS-server.

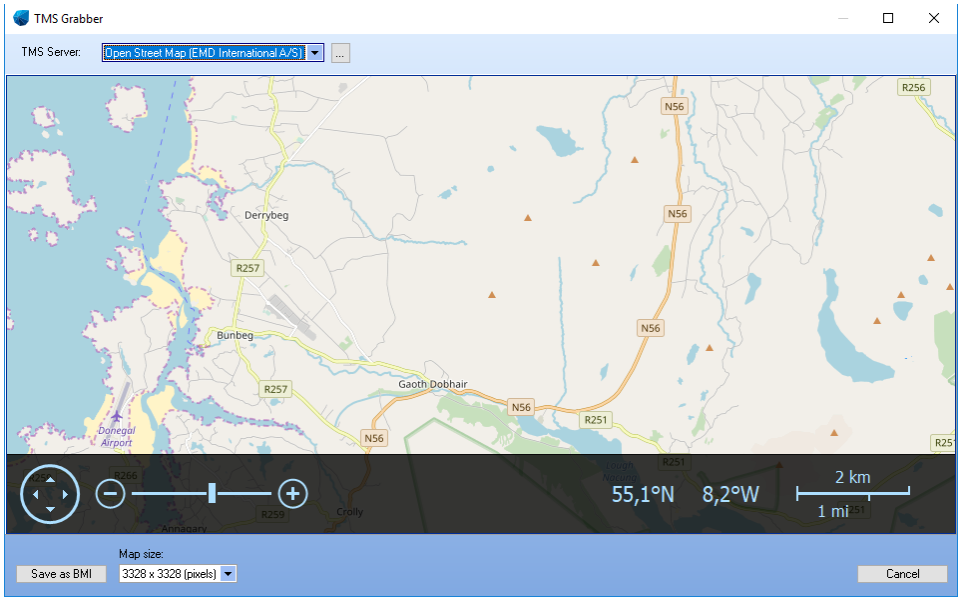


2.4.4.8 TMS

Import from TMS server

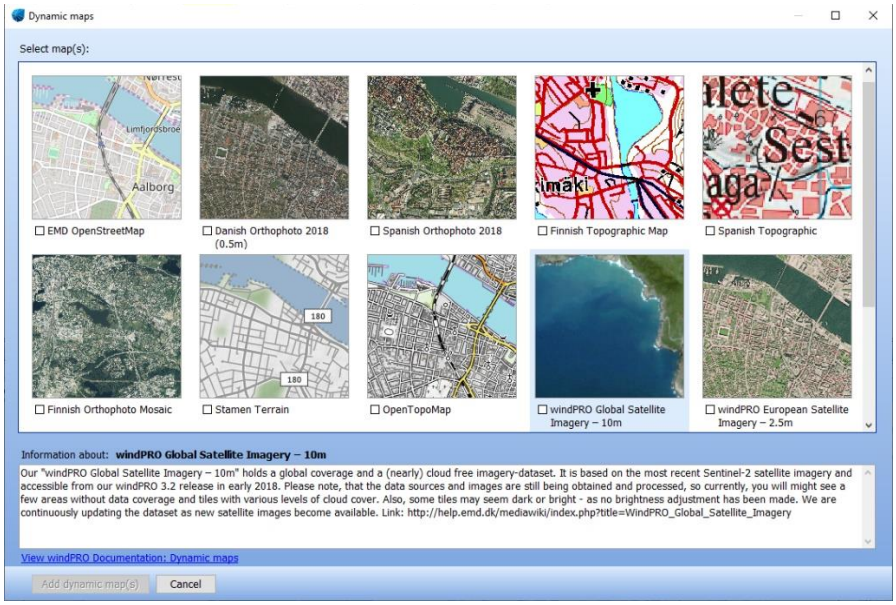
Just like WMS, the TMS is a standard protocol for serving georeferenced map images over the Internet that are pre-generated by a map server using data from a GIS database. Select a TMS Service from the dropdown list or add your own.

Unlike the WMS, the preview updates instantly. Select the desired image resolution and click Save as BMI.



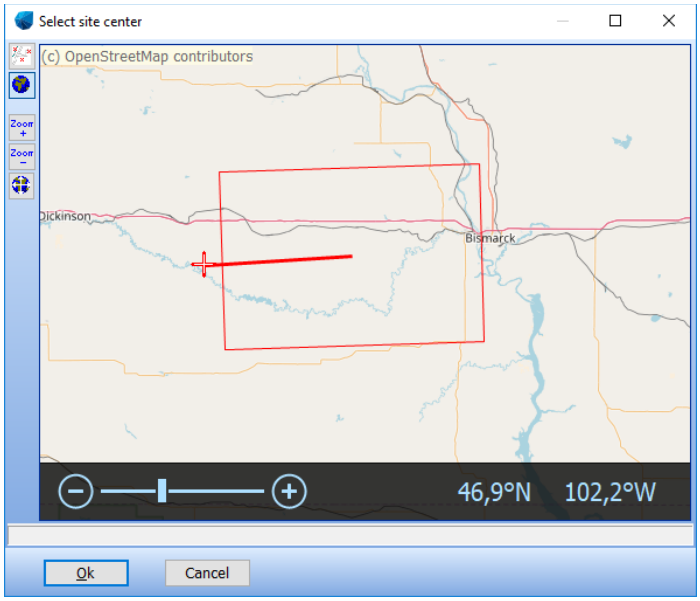
2.4.4.9 Dynamic maps

Dynamic maps are easy to use, as you don't have to specify any boundaries or scale for your map. Once a map source has been selected, the map will automatically adjust to the desired zoom level and new map tiles are downloaded automatically as you pan around your site.



2.4.4.10 View and set site center

When you click on one of the attached maps and then on the **View/set site center** button, the map will appear, showing if the site center is within the map area (see below). If the site center is outside the defined map, either move site center or redo the geo-reference.



In the example above, the rectangle shows the coverage of the attached map and the red cross shows the present location of the site center. The red line points to the center of the map that you are currently trying to view. To move site center inside the map, simply single click inside the red square.

2.4.4.11 Blank map

If no maps are available, you can still enter objects graphically by using a blank map, which is simply a white background that is automatically scaled to your project design area. A blank map appears automatically in every windPRO project.

2.4.4.12 Some map window features

In the top bar of the map window, you will find a series of buttons to the left:

The first one creates a .bmi file (windPRO's native background map format) from whatever is displayed in the map window. This .BMI file is then including "what you see" on the map, such as objects etc. The map is immediately loaded after pressing the button. If you have a large wind resource map file or detailed water depth map, that takes long time to render, it can be more efficient to have a "hard copy" as a background map where you save the render waiting time.

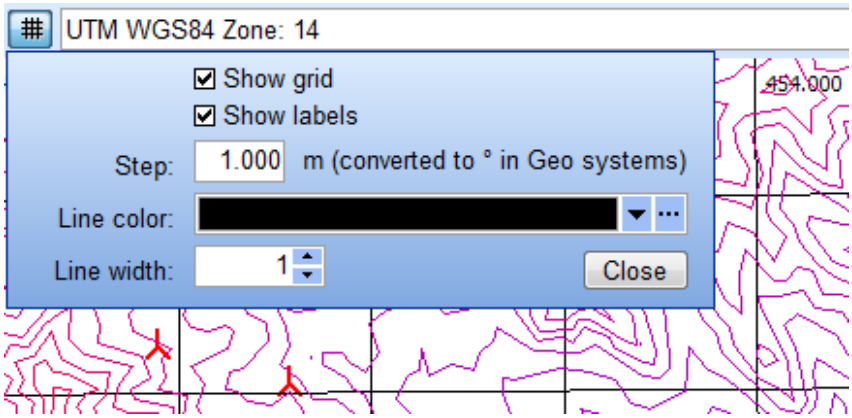
The second button simply copies the map to clipboard, for pasting into other programs such as Word for documentation reports.

The third button allows to get back the background map tab, where new maps can be added, or existing ones adjusted.

The fourth button is for adjustment of WMS or TMS maps. The icon is only shown when a WMS or TMS map is selected. By clicking on the icon it is possible to download more (or less) tiles and to change the resolution. The new resolution is defined by the zoom level on the current map. Less than 100% will lower the resolution (which can be useful to be able to cover a larger area since the maximum number of tiles is limited) and, for a zoom greater than 100%, the resolution will be increased. In this case, if the number of tiles is unchanged, the area covered will be smaller.

The fifth button is for the grid tool. It allows a grid to be shown in the selected coordinate system. It is possible to have the coordinates shown as labels and to define the properties of the grid.

The zoom, the coordinate system and coordinate zone can be changed at any time using the dropdown menus. Zoom can also be changed by scroll button on your mouse (or by certain touchpad functions on a laptop). Coordinate system choices can be limited to the country-specific ones. EMD maintain a list that pairs countries and coordinate systems.

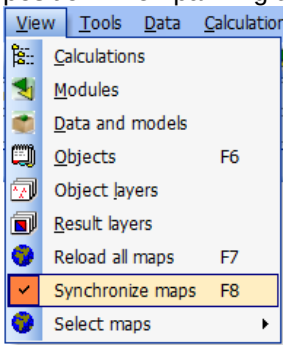


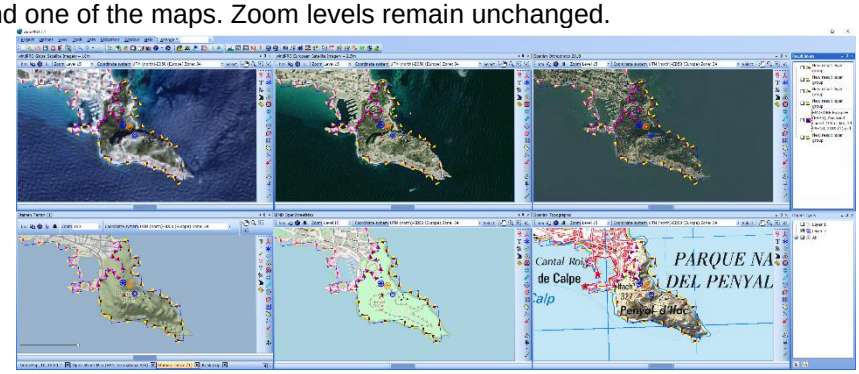
2.4.4.13 Merge maps

With the merge map button, more maps can be “glued” to one map, although it requires all has same scale. Simply press the button and select the maps to be glued in the browser. The glued map will then be saved in the list as a new map.

2.4.4.14 Synchronize maps

Going into the View menu and activating the Synchronize maps option, all maps will move to the same position when panning around one of the maps. Zoom levels remain unchanged.

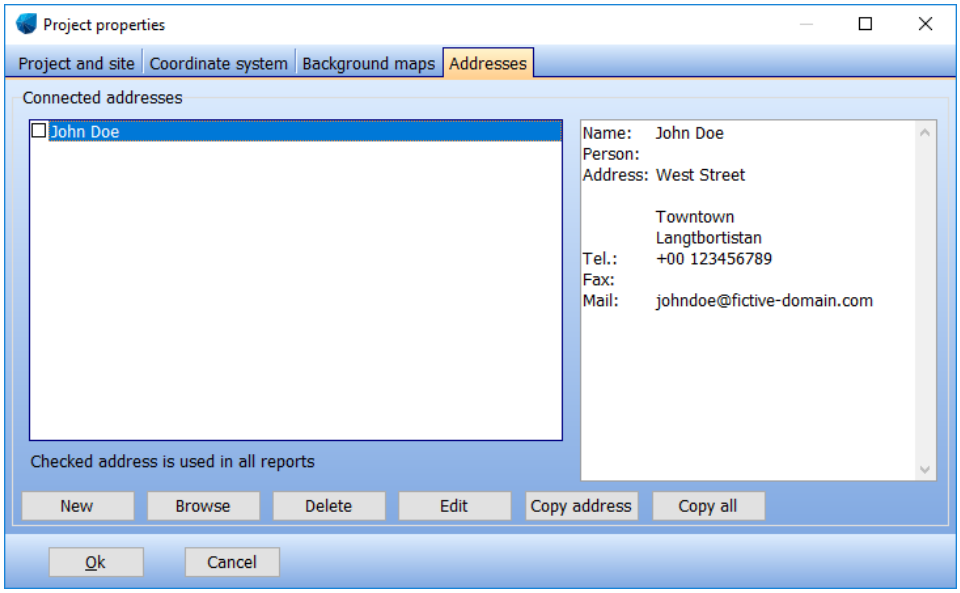




This makes it easy to compare different map sources at the same spot.

2.4.5 Project Properties: Addresses

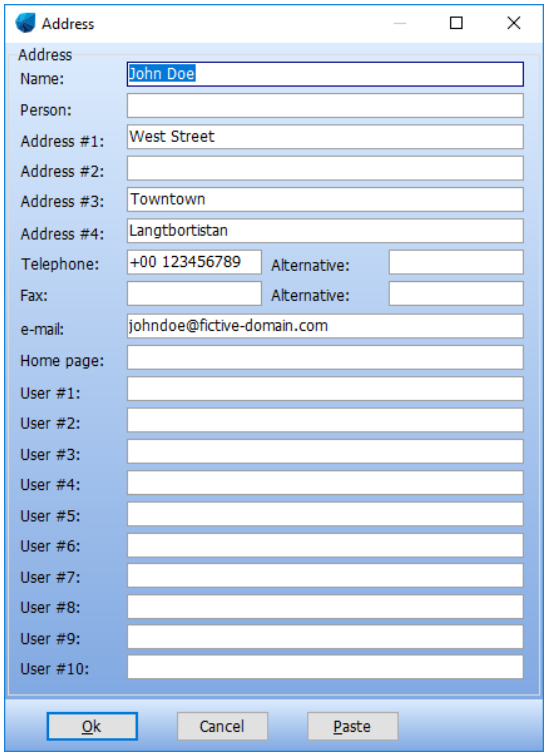
In the Address Tab Sheet shown below, you enter the address of the relevant customer, the electricity company, the county, etc. You can individually select the addresses, which determines whether each address will be printed on all printouts.



The buttons are as follow:

- **New**: Create a new address.
- **Browse**: Look in the list of addresses used in previous projects to use a previously typed address.
- **Delete**: Remove the highlighted address from the project.
- **Edit**: Edit the highlighted address.
- **Copy address**: Copy name, person and address to the clipboard in order to paste them into a text document e.g. a letter, a fax or an address label to send with the calculation reports.
- **Copy all**: Copy all fields in the address record to clipboard

Besides the fields shown in the screen above, you have some additional user-fields in which you can add project status, customer number referring to other customer databank, more telephone numbers, contact persons, etc. All fields are shown below. The field lengths are practically unlimited, but remember that if you wish to use them in other databases, there might be a limited field length.



2.4.5.1 Address list browser

When you browse for addresses, you will get a list of all addresses in previous projects which are included in the project browser search path.

When opened with the browse button from Project Properties; if you double-click on an address, windPRO will return the selected address. You can also return the address by highlighting and clicking on OK.

The address list can also be copied to other programs simply by making your selection the same as you would in the Windows Explorer (with the <Shift> key and/or the <Ctrl> key held down when clicking), then right-click and select **Copy**. The entire address list with all fields can then be pasted into a spreadsheet. This can be useful when making status reports on all projects or transferring addresses to other software programs as general customer databases.

2.5 BASIS – Project design, import/export, calculation, report

2.5.1 Introduction to establishing a project

When the project properties have been entered, the actual project design work can begin. In this section we will describe how WTGs or other objects are entered and how general object editing, copying and import/export works. Other object inputs will depend upon the calculations you wish to perform. These other object inputs are described in the relevant chapters.

2.5.1.1 Map

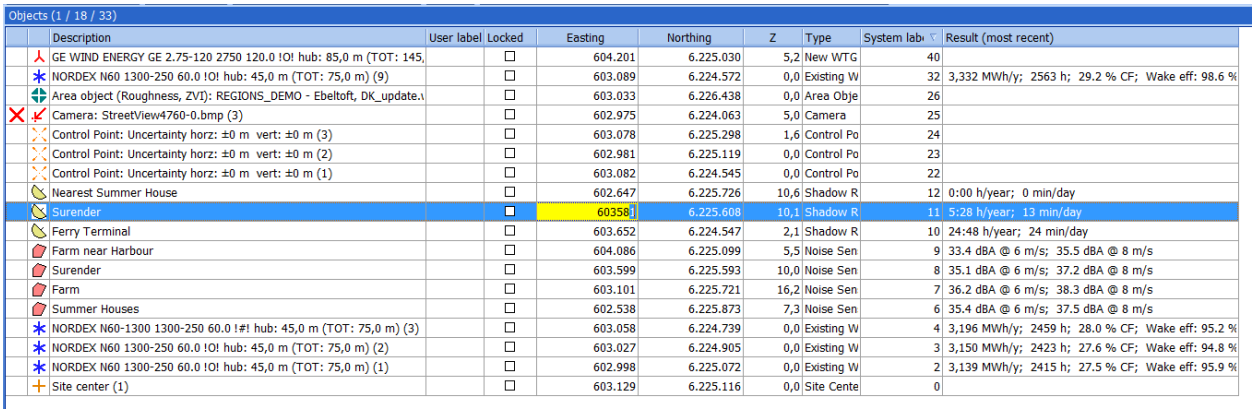
WTGs and other Objects can be placed on the map by selecting the object from the toolbar to the left of the map, and then clicking on the map.

If you wish to place multiple identical objects subsequently, simply hold down the <Shift> key while selecting an object from the toolbar. This way you can place several objects with the same object properties, e.g. a series of noise objects with the same distance and dB requirements, or a number of parallel rows of WTGs etc.

You can insert bookmarks on the maps by <Ctrl+k> <1> for marking the first of up to 10 bookmarks, then <Ctrl + 1> for GOTO bookmark 1, etc. Right –clicking on the map also brings up a bookmark menu. This makes it possible to move quickly between different “sweet spots” on your map. Bookmarks are not marked on the map and do not show up on the Object List.

2.5.1.2 Object List

The Object list displays all the objects located in the visible layers. In the Object List view, objects are marked with a red x if there are errors associated with the object (typically missing data that the object links to, or missing height information (TIN) where the object is placed). The latter error shows a red x in the Z-value column, only if the object is set to get its Z-value from the Digital Height Model (DHM), which in this case means the calculated Triangular Irregular Network (TIN) (see TIN).



Objects (1 / 18 / 33)

Description	User label	Locked	Easting	Northing	Z	Type	System lab	Result (most recent)
GE WIND ENERGY GE 2.75-120 2750 120.0 !O! hub: 85,0 m (TOT: 145,		☐	604.201	6.225.030	5,2	New WTG	40	
NORDEX N60 1300-250 60.0 !O! hub: 45,0 m (TOT: 75,0 m) (9)		☐	603.089	6.224.572	0,0	Existing W	32	3,332 MWh/y; 2563 h; 29.2 % CF; Wake eff: 98.6 %
Area object (Roughness, ZVI): REGIONS_DEMO - Ebeltoft, DK_update.\		☐	603.033	6.226.438	0,0	Area Obje	26	
Camera: StreetView4760-0.bmp (3)		☐	602.975	6.224.063	5,0	Camera	25	
Control Point: Uncertainty horz: ±0 m vert: ±0 m (3)		☐	603.078	6.225.298	1,6	Control Po	24	
Control Point: Uncertainty horz: ±0 m vert: ±0 m (2)		☐	602.981	6.225.119	0,0	Control Po	23	
Control Point: Uncertainty horz: ±0 m vert: ±0 m (1)		☐	603.082	6.224.545	0,0	Control Po	22	
Nearest Summer House		☐	602.647	6.225.726	10,6	Shadow R	12	0:00 h/year; 0 min/day
Surender		☐	60358	6.225.608	10,1	Shadow R	11	5:28 h/year; 13 min/day
Ferry Terminal		☐	603.652	6.224.547	2,1	Shadow R	10	24:48 h/year; 24 min/day
Farm near Harbour		☐	604.086	6.225.099	5,5	Noise Sen	9	33.4 dBA @ 6 m/s; 35.5 dBA @ 8 m/s
Surender		☐	603.599	6.225.593	10,0	Noise Sen	8	35.1 dBA @ 6 m/s; 37.2 dBA @ 8 m/s
Farm		☐	603.101	6.225.721	16,2	Noise Sen	7	36.2 dBA @ 6 m/s; 38.3 dBA @ 8 m/s
Summer Houses		☐	602.538	6.225.873	7,3	Noise Sen	6	35.4 dBA @ 6 m/s; 37.5 dBA @ 8 m/s
NORDEX N60-1300 1300-250 60.0 !#! hub: 45,0 m (TOT: 75,0 m) (3)		☐	603.058	6.224.739	0,0	Existing W	4	3,196 MWh/y; 2459 h; 28.0 % CF; Wake eff: 95.2 %
NORDEX N60 1300-250 60.0 !O! hub: 45,0 m (TOT: 75,0 m) (2)		☐	603.027	6.224.905	0,0	Existing W	3	3,150 MWh/y; 2423 h; 27.6 % CF; Wake eff: 94.8 %
NORDEX N60 1300-250 60.0 !O! hub: 45,0 m (TOT: 75,0 m) (1)		☐	602.998	6.225.072	0,0	Existing W	2	3,139 MWh/y; 2415 h; 27.5 % CF; Wake eff: 95.9 %
Site center (1)		☐	603.129	6.225.116	0,0	Site Cente	0	

In the Object List you can select several objects in the same way you would in Windows Explorer. The selection will then work on the map also. For example you can then move all the selected objects in one operation by dragging them to a new location on the map. Note also the right-click features available for selected objects in Object List, such as Delete, Edit, Copy or import/export.

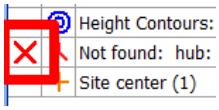
In the top line of the window, the word “Objects” is followed by three numbers. These numbers reflect the number of objects selected/visible/total (e.g. 1/18/33 above - 1 selected/18 visible/33 total).

Note the column “Results”, which show the most recent main calculation results for some selected objects like Noise Sensitive Areas or WTGs. These results can also be shown as labels on the map, and they can be copied to clipboard – a very efficient way when analyzing a special case where many different smaller adjustments are performed.

A special feature for Line or Area Objects is the ability to center the object at the point where the linked data is on the map. This may help you find where the imported data in line or Area Objects are located and then possibly locate import errors.

It is possible to edit the object data directly in the object list, without opening the object. For example, coordinates, user labels, description – just click on the cell and it turns yellow. Different right-click actions are available when the individual cell is highlighted yellow, and when the entire line is highlighted blue.

Any object can be copied from one open windPRO project and pasted into another open windPRO project. However, the two projects must be located within ± 1 UTM zone. The target project may not have all the information as the source project, like elevation, data objects etc. so a red cross will possibly appear in the object list informing you to update the object properties in the new project.



2.5.2 Entering, moving, snapping, and selecting WTGs (and other objects)

WTGs can be created as individual WTGs or as rows with fixed in-row distance and WTG type. It's always possible to turn a row into individual WTGs (with a right-click to "split row") and still be able to edit the coordinates and WTG type individually afterwards. The WTG type must be listed in the WTG Catalogue and so, must first be created in the Catalogue if not already listed in it.

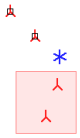
Moving an object:
There are three ways of moving an object

1. Mouse
2. Keyboard arrows
3. Coordinate input

To move an object with the mouse you can position it at the correct location by clicking on the symbol on the map so it is selected (small black square in centre of symbol) and dragging it to the desired location on the map with the hand tool.
Multiple objects can be selected by holding down the CTRL key and clicking on the desired symbols.
You can also use the "select with box" or "select with polygon" tools, selecting all objects contained in the area you draw. Note: These tools are only available in window layouts created since version 3.3.

Holding down the <CTRL> key will also snap/link your mouse cursor to the nearest object. If you are moving an object while holding the <CTRL> key, that object will be linked to the nearest snapped object.

Holding down the <SHIFT> key while clicking and dragging the mouse will create a selection box. All objects inside the selection box will be selected when letting go of the left mouse button. By keeping the <SHIFT> button pressed, multiple selection boxes can be merged together.

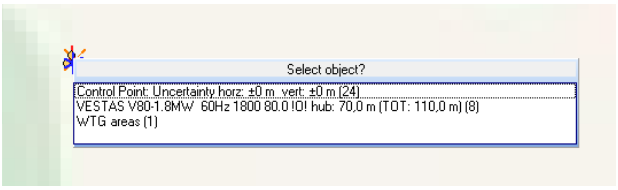


Once one object has been linked to another, it cannot be moved. To unlink, simply right click the object on the map and uncheck the **Linked to** setting.

To move an object with the keyboard, hold down the <Ctrl> key and move the selected object with the arrow keys.

The third way of moving an object is to manually change the coordinates of the object in the Object list, or from the Object Properties.

If multiple objects are positioned close together, it can be difficult to aim the cursor at the right object. Simply move the cursor over the group of objects to get a drop-down list of the objects. You can then select the one you wish to move or enter properties for.



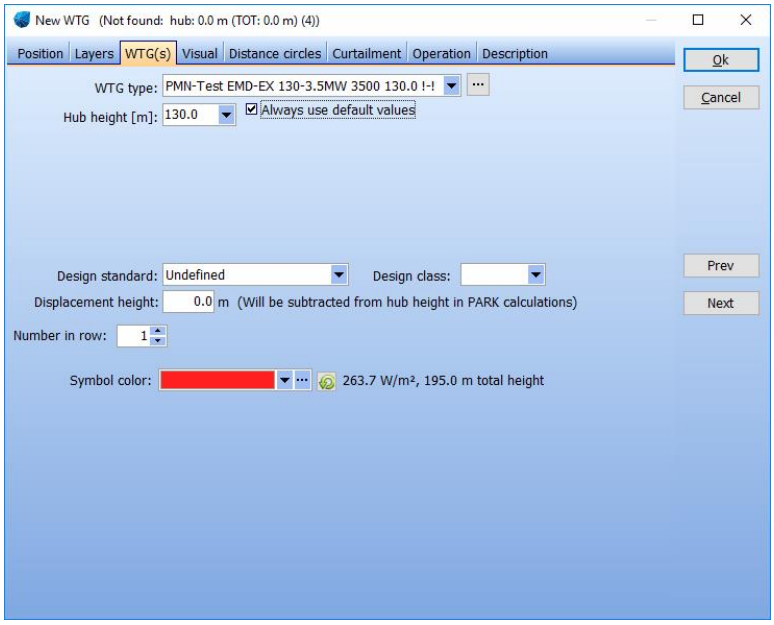
For rows of WTGs the following rule applies:

Place the cross hair inside the center mark, left-click and drag to move the row parallel to its original position. Place the cross hair inside an outer mark to rotate the row around the opposite outer mark. Hold down the <Shift> key while dragging an outer mark to change the in-row distance.

To “mass create” an object, hold down the <Shift> key while selecting an object from the toolbar. Once the object properties have been defined, you can single click on the map again to create a new object identical to the first one. Right click anywhere on the map, or hit the ESC key to stop the mass creation.

2.5.2.1 WTG Object Tab Sheet: WTG(s)

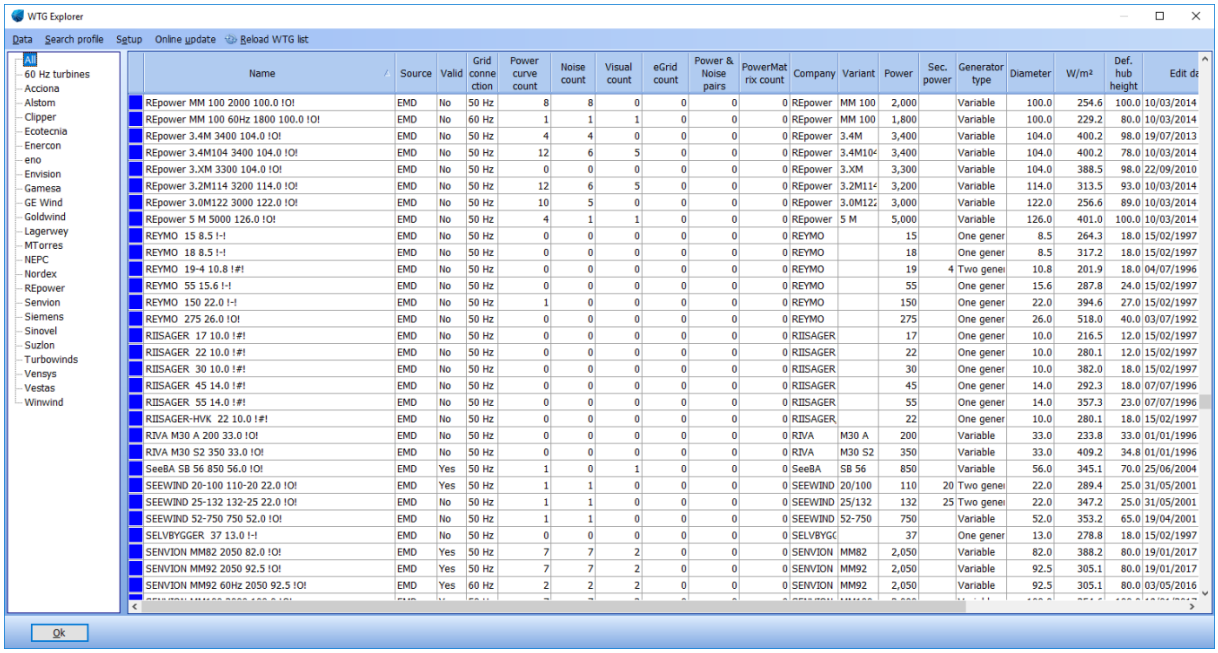
Activating the **new WTG** icon creates new WTGs by clicking on the desired position on the map. The following window will appear.



Entering new WTGs:

With the **Number in row** it's possible to create not only one WTG at a time, but also a row of WTGs with same in-row distance and on a straight line.

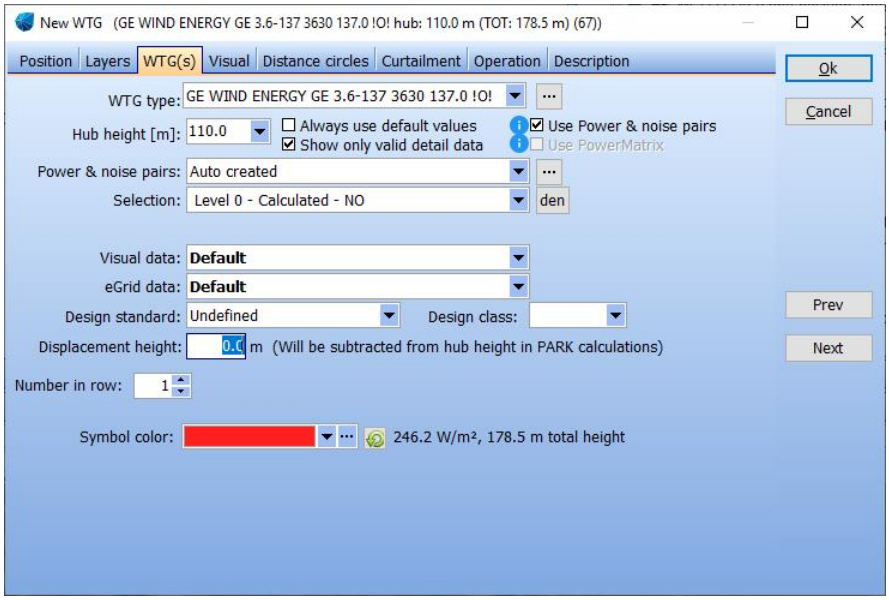
The WTG type is selected from the WTG Catalogue via the drop-down list, which holds the last 10 WTGs used. Select <more WTGs> to access the WTG Explorer (see figure below), where you can build different search profiles and select these in the WTG Explorer. This makes the searching and selecting of a specific WTG type easier and faster. Note from the Setup you can edit the search path, and thereby decide where to browse for turbines (in which folders). By default you browse in the windPRO Data\WTG folder and the current project folder.



Name	Source	Valid	Grid connection	Power curve count	Noise count	Visual count	eGrid count	Power & Noise pairs	PowerMatrix count	Company	Variant	Power	Sec. power	Generator type	Diameter	W/m²	Def. hub height	Edit da
REpower MM 100 2000 100.0 !O!	EMD	No	50 Hz	8	8	0	0	0	0	REpower	MM 100	2,000		Variable	100.0	254.6	100.0	10/03/2014
REpower MM 100 60Hz 1800 100.0 !O!	EMD	No	60 Hz	1	1	1	0	0	0	REpower	MM 100	1,800		Variable	100.0	229.2	80.0	10/03/2014
REpower 3.4M 3400 104.0 !O!	EMD	No	50 Hz	4	4	0	0	0	0	REpower	3.4M	3,400		Variable	104.0	400.2	98.0	19/07/2013
REpower 3.4M104 3400 104.0 !O!	EMD	No	50 Hz	12	6	5	0	0	0	REpower	3.4M104	3,400		Variable	104.0	400.2	78.0	10/03/2014
REpower 3.XM 3300 104.0 !O!	EMD	No	50 Hz	0	0	0	0	0	0	REpower	3.XM	3,300		Variable	104.0	388.5	98.0	22/09/2010
REpower 3.2M114 3200 114.0 !O!	EMD	No	50 Hz	12	6	5	0	0	0	REpower	3.2M114	3,200		Variable	114.0	313.5	93.0	10/03/2014
REpower 3.0M122 3000 122.0 !O!	EMD	No	50 Hz	10	5	0	0	0	0	REpower	3.0M122	3,000		Variable	122.0	256.6	89.0	10/03/2014
REpower 5 M 5000 126.0 !O!	EMD	No	50 Hz	4	1	1	0	0	0	REpower	5 M	5,000		Variable	126.0	401.0	100.0	10/03/2014
REYMO 15 8.5 !-!	EMD	No	50 Hz	0	0	0	0	0	0	REYMO		15		One gener	8.5	264.3	18.0	15/02/1997
REYMO 18 8.5 !-!	EMD	No	50 Hz	0	0	0	0	0	0	REYMO		18		One gener	8.5	317.2	18.0	15/02/1997
REYMO 19-4 10.8 !#!	EMD	No	50 Hz	0	0	0	0	0	0	REYMO		19	4	Two gene	10.8	201.9	18.0	04/07/1996
REYMO 55 15.6 !-!	EMD	No	50 Hz	0	0	0	0	0	0	REYMO		55		One gener	15.6	287.8	24.0	15/02/1997
REYMO 150 22.0 !-!	EMD	No	50 Hz	1	0	0	0	0	0	REYMO		150		One gener	22.0	394.6	27.0	15/02/1997
REYMO 275 26.0 !O!	EMD	No	50 Hz	0	0	0	0	0	0	REYMO		275		One gener	26.0	518.0	40.0	03/07/1992
RIISAGER 17 10.0 !#!	EMD	No	50 Hz	0	0	0	0	0	0	RIISAGER		17		One gener	10.0	216.5	12.0	15/02/1997
RIISAGER 22 10.0 !#!	EMD	No	50 Hz	0	0	0	0	0	0	RIISAGER		22		One gener	10.0	280.1	12.0	15/02/1997
RIISAGER 30 10.0 !#!	EMD	No	50 Hz	0	0	0	0	0	0	RIISAGER		30		One gener	10.0	382.0	18.0	15/02/1997
RIISAGER 45 14.0 !#!	EMD	No	50 Hz	0	0	0	0	0	0	RIISAGER		45		One gener	14.0	292.3	18.0	07/07/1996
RIISAGER 55 14.0 !#!	EMD	No	50 Hz	0	0	0	0	0	0	RIISAGER		55		One gener	14.0	357.3	23.0	07/07/1996
RIISAGER-HVK 22 10.0 !#!	EMD	No	50 Hz	0	0	0	0	0	0	RIISAGER		22		One gener	10.0	280.1	18.0	15/02/1997
RIVA M30 A 200 33.0 !O!	EMD	No	50 Hz	0	0	0	0	0	0	RIVA	M30 A	200		Variable	33.0	233.8	33.0	01/01/1996
RIVA M30 S2 350 33.0 !O!	EMD	No	50 Hz	0	0	0	0	0	0	RIVA	M30 S2	350		Variable	33.0	409.2	34.8	01/01/1996
SeeBA SB 56 850 56.0 !O!	EMD	Yes	50 Hz	1	0	1	0	0	0	SeeBA	SB 56	850		Variable	56.0	345.1	70.0	25/06/2004
SEEWIND 20-100 110-20 22.0 !O!	EMD	Yes	50 Hz	1	1	0	0	0	0	SEEWIND	20/100	110	20	Two gene	22.0	289.4	25.0	31/05/2001
SEEWIND 25-132 132-25 22.0 !O!	EMD	No	50 Hz	1	1	0	0	0	0	SEEWIND	25/132	132	25	Two gene	22.0	347.2	25.0	31/05/2001
SEEWIND 52-750 750 52.0 !O!	EMD	No	50 Hz	1	1	0	0	0	0	SEEWIND	52-750	750		Variable	52.0	353.2	65.0	19/04/2001
SELVBYGGER 37 13.0 !-!	EMD	No	50 Hz	0	0	0	0	0	0	SELVBYGG		37		One gener	13.0	278.8	18.0	15/02/1997
SENVION MM82 2050 82.0 !O!	EMD	Yes	50 Hz	7	7	2	0	0	0	SENVION	MM82	2,050		Variable	82.0	388.2	80.0	19/01/2017
SENVION MM92 2050 92.5 !O!	EMD	Yes	50 Hz	7	7	2	0	0	0	SENVION	MM92	2,050		Variable	92.5	305.1	80.0	19/01/2017
SENVION MM92 60Hz 2050 92.5 !O!	EMD	Yes	60 Hz	2	2	2	0	0	0	SENVION	MM92	2,050		Variable	92.5	305.1	80.0	03/05/2016

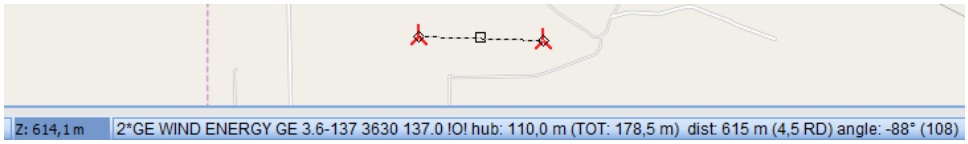
In the list you can sort by the different columns by clicking in the header bar of the column.

After having selected a WTG, it's possible to look for different power curves, noise data etc. by deselecting **Always use default** (see below).



The two options **Use Power & noise pairs** and **Use PowerMatrix** will be explained in section 2.6.3.3 and 2.6.3.4.

After having entered the WTGs on a map it's easy to move them as any other object. As a row object, you can activate and drag an outer selection mark to rotate the row. Activate an outer selection mark while holding down the <Shift> key in order to change the in-row distance between the WTGs.



In the info field at the bottom of the map screen, the row bearing and distance in meters as well as in Rotor Diameter (RD) is shown continuously updated, as well the hub height as total height (TOT) is shown.

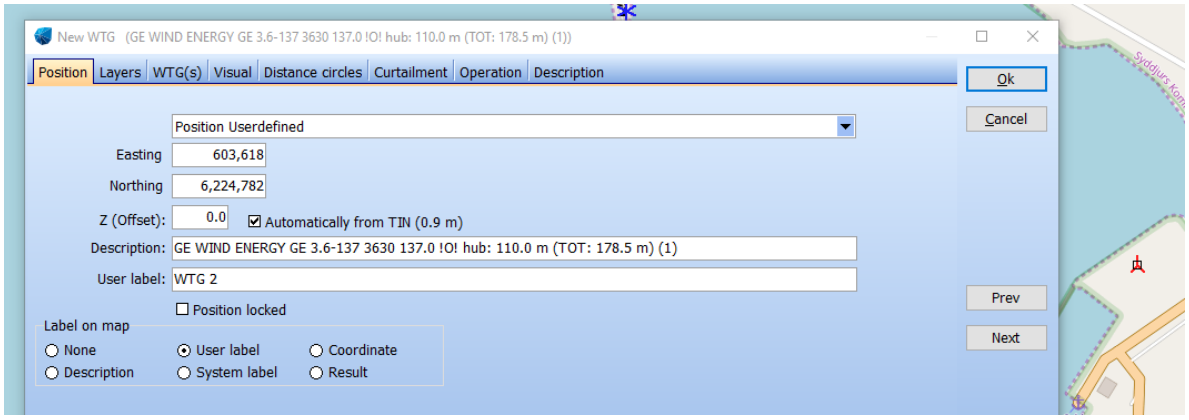
2.5.2.2 Object Tab Sheet: Position

By right-clicking and selecting Properties, the input window for a WTG or any other object will appear, and more details can be entered. The Tab Sheet **Position** is common for all objects. Here you can enter the exact coordinates. The Z-coordinate can be entered or read automatically from a Digital

Terrain Model calculated on the BASIS of a Line Object (Height Contour Map), but then the object has to be inside the TIN radius, see Line Object Section. A “Description” can be entered and used as label on map. It’s shown in the Object List and will be shown on printouts too. You can also enter a "User Label". The software automatically gives a "System Label", where the first created object gets no. 1, the second no.2 etc. These system labels can never be changed (even if objects are deleted, their System Labels are not reused). Therefore you have the opportunity to assign your own user label to objects, e.g. for a special numbering order in your WTGs or other objects. Later on (in “Printing Reports”), you can choose to sort the WTGs by user label instead of system label and thereby obtain full control. If you use letters in the user label, normal alphabetic sorting will be used.

On the map, the following labels can be made visible next to the object:

Description,
User label,
System label
Coordinates or
None



NOTE: Performing a WAsP calculation, an entered Z-value does not make any difference in calculation result. This calculation will always define the Z value based on the elevation data. However, the Z-value can be used in visualizations and environmental calculations.

2.5.2.3 Existing WTGs Tab Sheet: WTG(s)

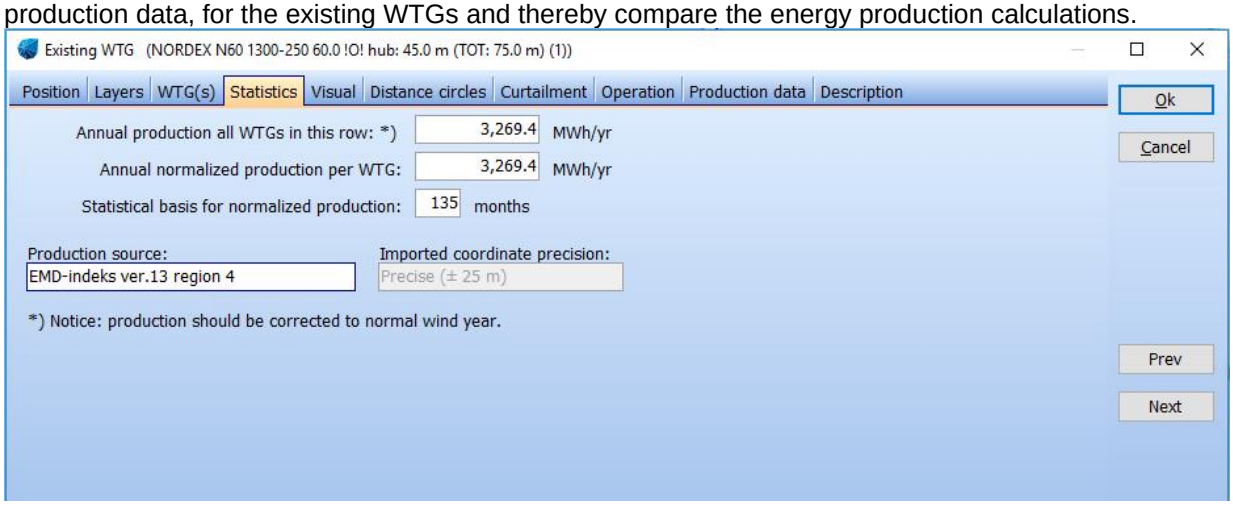
Existing WTGs are created the same way as the new WTGs. In a PARK calculation the results will be grouped in new and existing WTGs respectively, including information on the impact of the new WTGs on the production of the existing WTGs.

Treat as PARK WTG checkbox means: If checked, the turbine is handled as a part of the wind farm to be calculated. The results for the existing PARK WTGs will appear at main results and take part in the PARK Total as well e.g. in time varying calculation results.

If NOT checked (default), the existing turbines are considered as “reference turbines” and are reported on separate page and do not take part in the totals or time varying results. As reference turbines it is possible to get a check of calculated versus actual production (Goodness) as part of the reference turbine print.

2.5.2.4 Existing WTGs Tab Sheet: Statistics

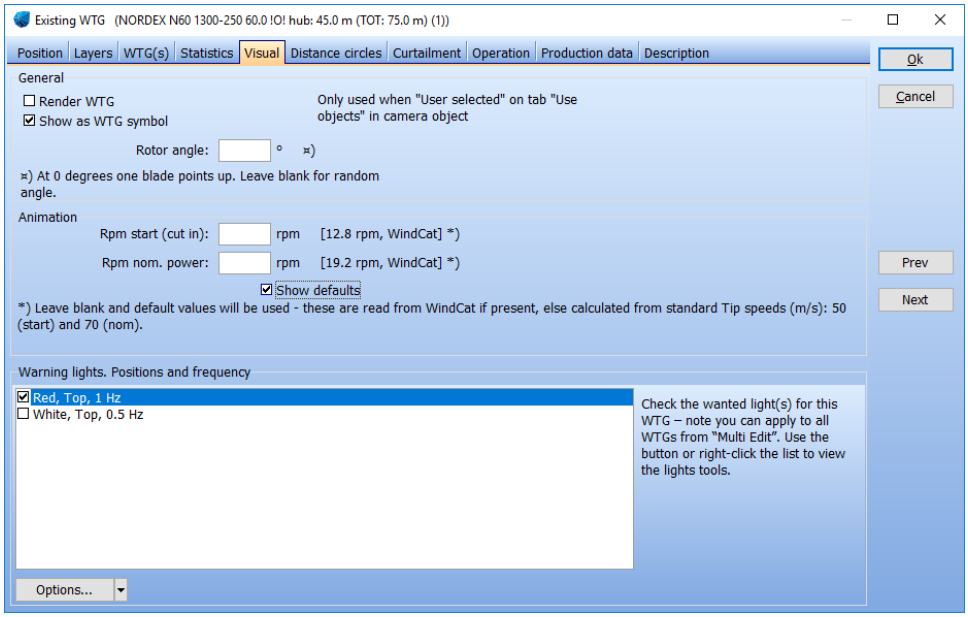
A difference from the New WTG object, is that it is possible to input statistical data, i.e. actual production data, for the existing WTGs and thereby compare the energy production calculations.



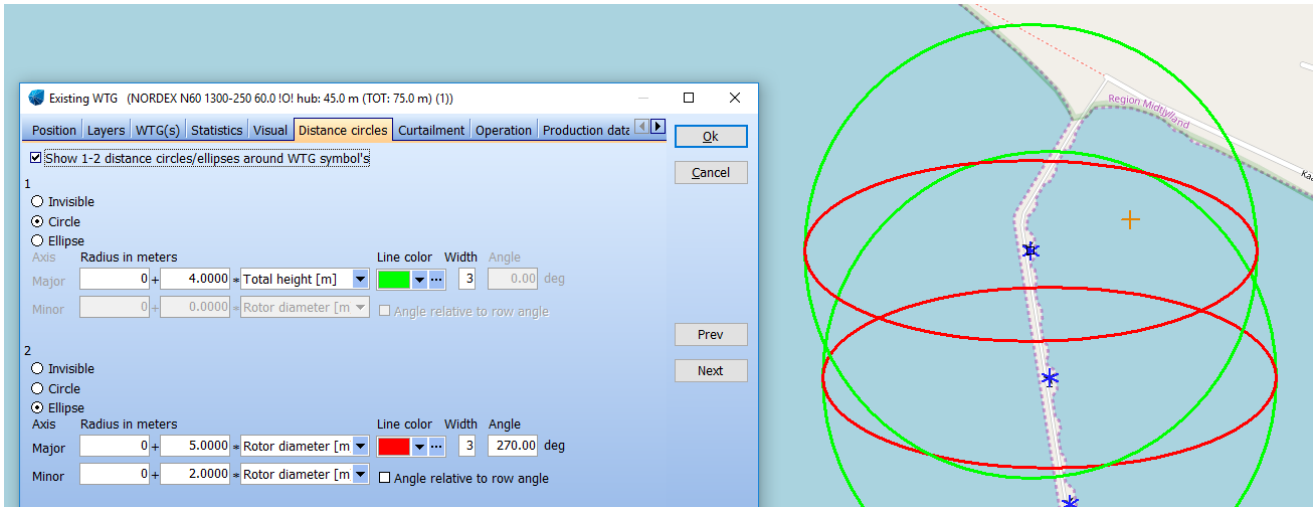
The tab **Production data** is for more detailed production data, which can be used with the Performance Check module, see Chapter 11.

2.5.2.5 WTG Object Tab Sheet: Visual

Here, the rotor angle and the rotational speed for the WTG rotor can be specified, and the Aviation light marking can be defined (see Chapter 7). A rotor angle of 0° will have one blade shown as vertical in PHOTOMONTAGE views (for a three-bladed turbine).

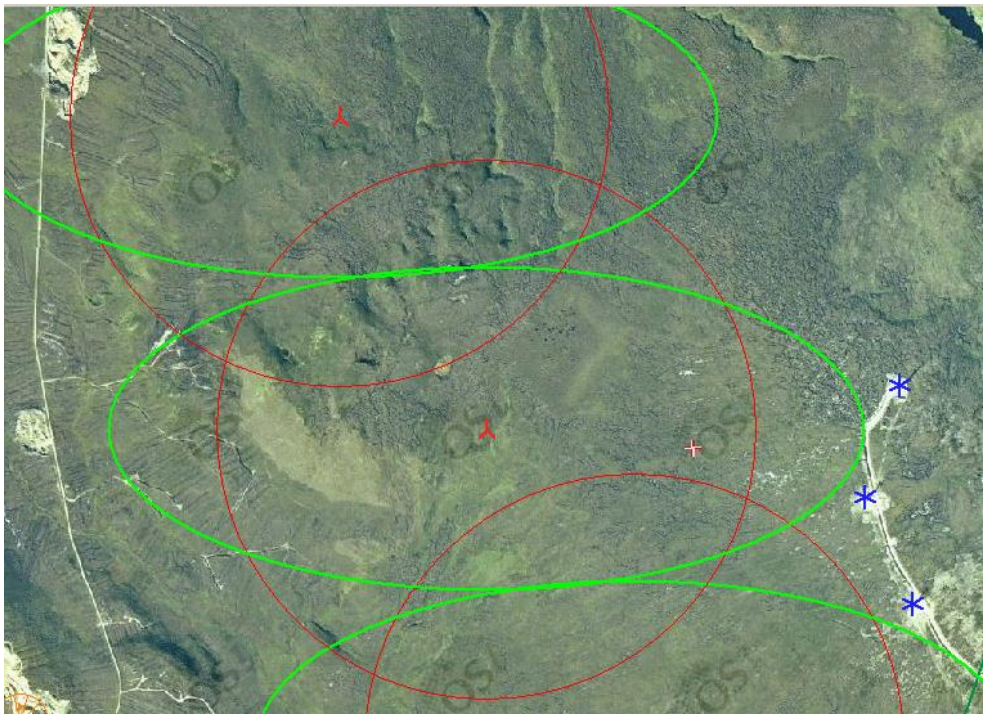


2.5.2.6 WTG Object Tab Sheet: Distance circles



In the Tab Sheet **Distance circles** you can enter:

Distance circle/ellipses – this is often useful for project design. It's activated by right-clicking on WTG symbol and checking **Show distance circle**. Two circles/ellipses can be established and the radius can be made dependent on WTG main size specifications. Color and line width can also be specified.



An example of how to use the distance circles to both ensure the distance to settlements (law requirements) and to existing turbines (turbulence).

2.5.2.7 Object Tab Sheet: Layer

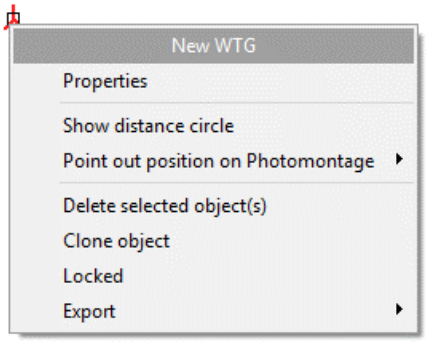
(See Layer Structure)

2.5.3 Clone object (copy), multi-editing, import

Two useful tools are available for all types of objects.

2.5.3.1 Clone object

Select one or more objects to clone (copy) from the map or the Object List. Select an object simply by clicking on the object with the left mouse button. Select additional objects by holding down the <Ctrl> key when clicking on objects on the map or multi-select in the Object List as you would in Windows Explorer or used the new selection tools in the map window. Once the objects have been selected, click on the right mouse button, then select **Clone Object** (go to the right from the top of the menu "New WTG | Map >" and a local object menu appears) (see below).

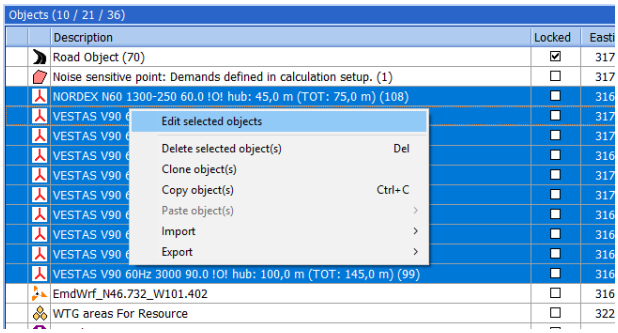


The cloned objects are placed 100 m East and 100 m south east of the original ones unless the original object positions are locked, in which case the cloned objects will be positioned at the exact same coordinates as the originals. In this case, the newly-cloned objects need to be unlocked before they can be moved. Cloning is a useful feature, especially for the terrain data object, since you don't have to enter values twice e.g. two roughness classifications nearby each other that are almost identical. It's also a good way to ensure that parallel rows of WTGs have identical properties.

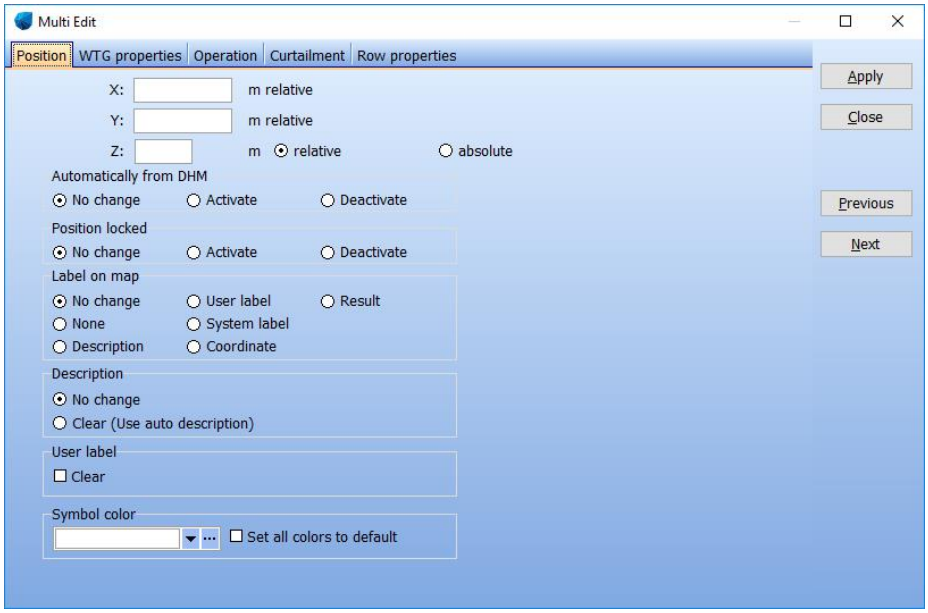
It is also possible to just Copy/Paste the object within the object list. In this case the object will be identical and positioned exactly at the same coordinates. This feature is useful when a set of objects has to be duplicated, for example two layouts of turbines with a different type for each. Entire layers can also be duplicated from the Layers Menu

2.5.3.2 Multi-editing

When working with many WTGs or other objects such as noise sensitive areas, where you need to change the WTG type in general, the hub height or noise emission data, or attach all objects to a height contour Line Object in order to read the Z-coordinates automatically, multi-editing is an efficient way of changing the characteristics for a large number of objects. Start by holding down <Shift> or <Ctrl> and selecting multiple objects in the object list or use the new selection tools on the map view.



Select the object to Edit from the object list and right click. Choose **Edit selected objects**.

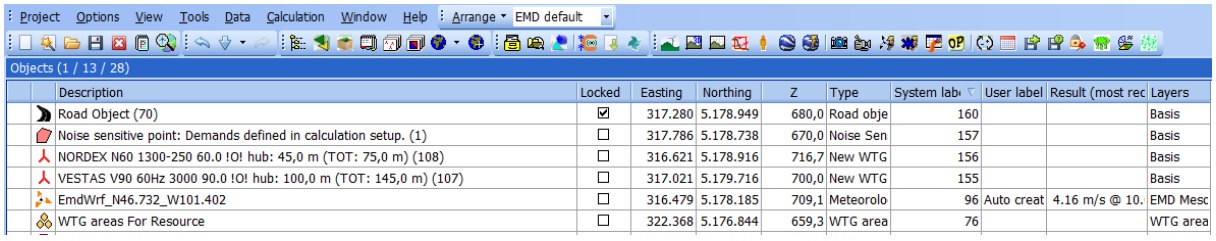


Select which properties to edit as shown above, e.g. automatically from DHM and Label on map from User Label. Only the relevant changes for each object are performed. The program will notify you of the different selected types of objects before handling.

2.5.4 Import/export and copy/paste of object data

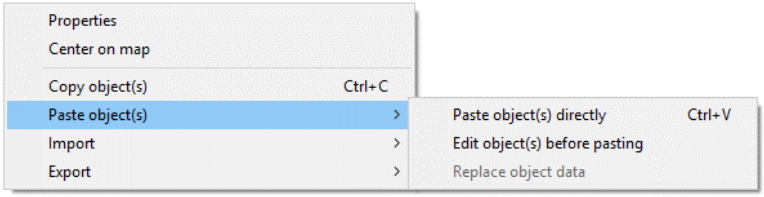
You may receive coordinates for objects (WTGs, neighbors, etc.) in a digital form that you don't wish to enter manually. Or, you need to make some changes to a wind farm layout with the aid of a spreadsheet calculation. Maybe you want to copy all noise sensitive areas to shadow receptors at the same positions, or copy a roughness rose from one project to another. All of these operations as well as many others can be performed with help from the import/export and copy/paste functions.

The Object List window shown below is from where these functions typically are used. But it is also possible to export by right click on an object on the map and export from there.



	Description	Locked	Easting	Northing	Z	Type	System lab	User label	Result (most rec	Layers
	Road Object (70)	☑	317.280	5.178.949	680,0	Road obje	160			Basis
	Noise sensitive point: Demands defined in calculation setup. (1)	☐	317.786	5.178.738	670,0	Noise Sen	157			Basis
	NORDEX N60 1300-250 60.0 !O! hub: 45,0 m (TOT: 75,0 m) (108)	☐	316.621	5.178.916	716,7	New WTG	156			Basis
	VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (107)	☐	317.021	5.179.716	700,0	New WTG	155			Basis
	EmdWrf_N46.732_W101.402	☐	316.479	5.178.185	709,1	Meteorolo	96	Auto creat	4.16 m/s @ 10.	EMD Mesc
	WTG areas For Resource	☐	322.368	5.176.844	659,3	WTG area	76			WTG area

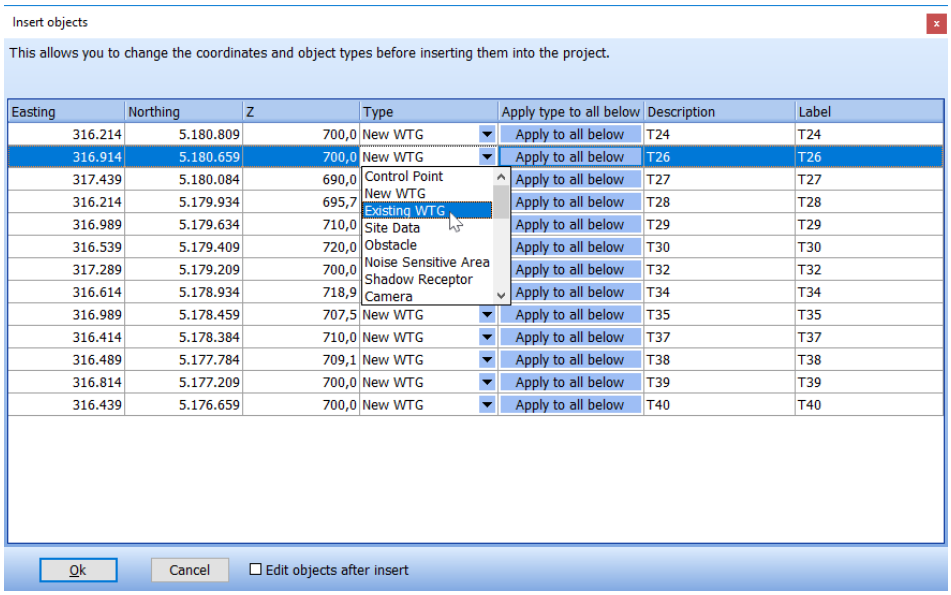
To export (copy) one or more objects, simply mark the objects by dragging when holding left mouse button down or, as in Windows Explorer, by holding down the <Ctrl> key or, by marking the first selection and then holding down the <Shift> key when marking the last. When objects are selected, right-click and get the menu shown below:



Choose **Copy object(s)** and all the stored information for the objects is placed in the Windows clipboard. The data can be pasted back as new objects or as a replacement of the copied data with the changes made in a spreadsheet, e.g. adding a user label (see next section).

Pasting objects from the clipboard can be done with <Ctrl>+<V>, or by right clicking the Object list selecting **Paste object(s) >** and then **Paste object(s) directly**.

If you want to change the objects before pasting them, you can select the **Edit object(s) before pasting** option. This way it is possible to convert a New Turbine into an Existing turbine, for example, or to convert a Control Point into a Meteo object. You can also use <Ctrl> <Shift> <V> to paste the objects and you will be prompted to change the object type.



Objects can also be easily created just by pasting coordinates from a spreadsheet to the object list of windPRO. Then the window above allows you to select which type of objects will be created. Note that different types of objects can be created. If it is the same type of object, click on **Apply to all Below**. The Description and Label can also be edited in this window.

2.5.4.1 Copy/paste for remote editing of object data in spreadsheet

From the clipboard, you simply paste the objects into a spreadsheet (or into the Object List in another project) and if into a spreadsheet, the list appears as shown below.

Descriptio	Object type	System lal	Object ID	X	Y	Z	Object de	User label	File name	Hub heigh	Productio	Use defau	Power cur
9850	Existing WTG	5	1	186530	424058	325,6	9850		C:\Users\	40,5	2383	yes	
9852	Existing WTG	6	1	186308	424183	332,5	9852		C:\Users\	40,5	2501	yes	
9853	Existing WTG	7	1	186220	424382	345	9853		C:\Users\	40,5	2632	yes	
9851	Existing WTG	8	1	186224	423942	289,7	9851		C:\Users\	40,5	2346	yes	
9854	Existing WTG	9	1	186442	423838	287	9854		C:\Users\	40,5	2321	yes	
		Paste from here if you want to replace object data											
			Paste from here if you want to create new object by type										
				Paste from here if you want to get a pop up list for selecting object type									

The following properties are common for all object types:

Description – Same as in Object description

Object type – Name, identifying type of object.

(The properties listed above will not be used when copying changed object data back to the Object List. Only those below will be used).

System label – unique internal number assigned when the new object is created (cannot be edited).

Object ID – Number OR Text, identifying the type of object (see List of Object Ids)

X – Easting coordinate

Y – Northing coordinate

Z – Elevation (above sea level)

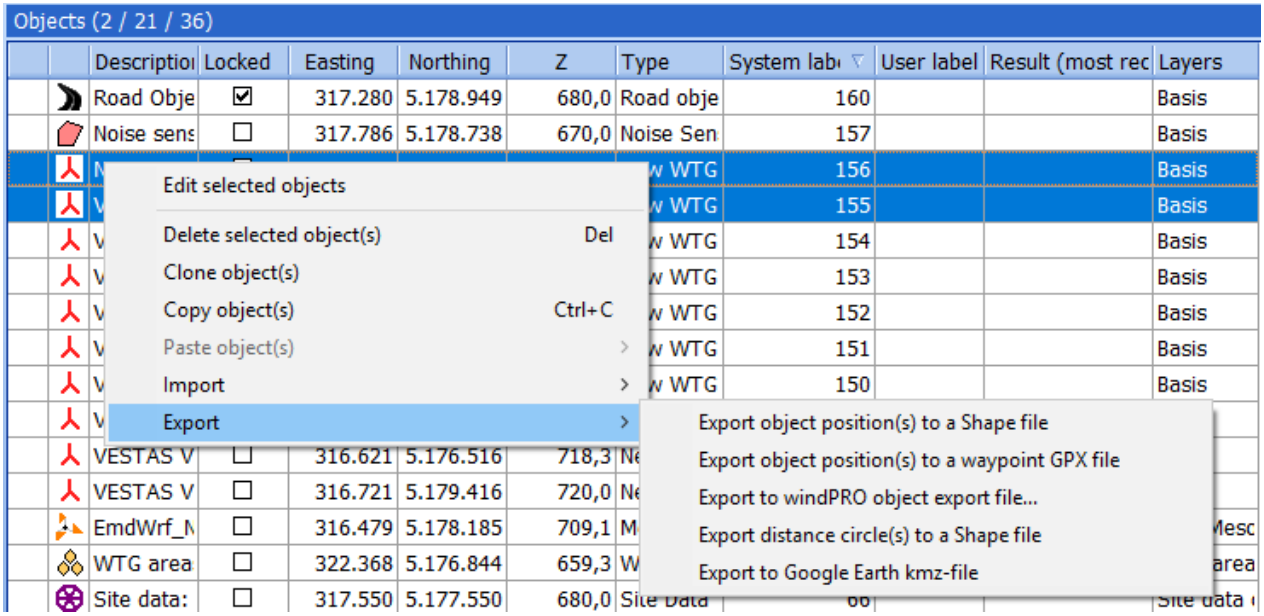
Object description - (User specified description, if no user description it is auto generated)

User label - (User label e.g. internal numbering for sorting in printout)

Lastly, depending of the type of object, additional information such as **Hub height** and **WTG type** for WTGs.

Data can now be modified in the spreadsheet and copied back to object list, see what to include in list shown above.

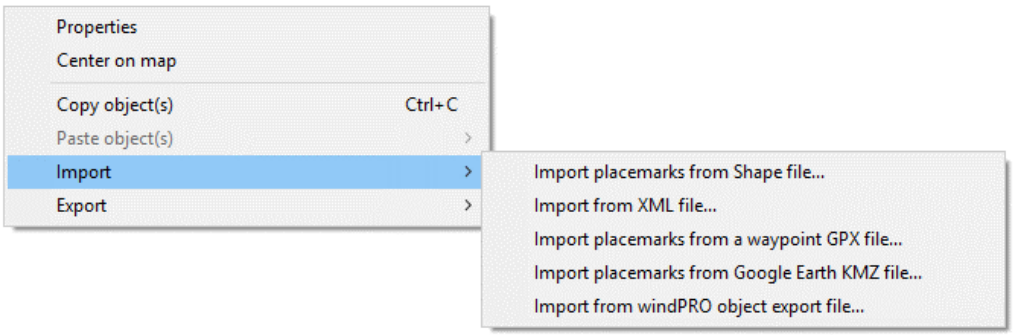
2.5.4.2 Export data from object list



There are at present five export options:

- The position to ESRI Shape files (for import in GIS software), a .shp file is created.
- To a waypoint GPX file, the “generic standard” within GPS, meaning this is the format that can be imported into a GPS.
- To file – a windPRO object file (.wpobjects) is created – this is an efficient way to transport objects from one windPRO project to another – this includes all data “behind” the objects.
- The distance circle to Shape files (only for wind turbine objects and requires that a distance circle is defined in the properties of the wind turbine)
- To Google Earth .kmz file, see Google Earth

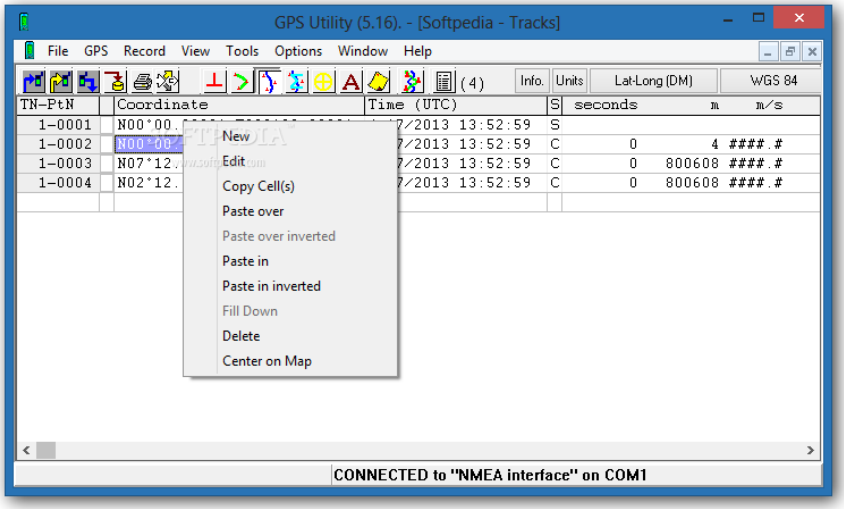
2.5.4.3 Import data to object list



Here are at present five different options:

- Import the position from Shape file
- Import from xml file (see knowledgebase)
- Waypoints from a GPX file, the generic GPS file format, see additional options about GPS coordinates below.
- From Google Earth kmz file, the points in the file (e.g. turbine positions specified by client) will be established as control marks in windPRO. Copying to a spreadsheet and pasting back you can change the control marks to the required object type.
- From file – the native windPRO *.wpobjects can be imported including all object information.

If you have data in a GPS, you need to extract the data into a spreadsheet before copying. This can be done simply by typing data from the GPS screen into a spreadsheet. Or, in the case of a larger number of GPS points, by importing GPS data into a PC (a special cable may be required to do this). Free software can be found on the Internet – e.g. at www.gpsu.co.uk, or included with your GPS. Shown below is an example of the screen in the free GPS software, GPS Utility, after downloading waypoints.



To get the coordinates pasted into a spreadsheet, you need to select one row at a time and then paste. Afterwards, you have to divide the coordinate column into two in the spreadsheet e.g. in Excel, use the "MID(A1;5;6)" function to extract, starting with the 5th character, the following 6 characters from cell A1 (the X-coordinate).

2.5.4.4 Identify what can be copy/pasted by object list

While the attributes that can be copied/pasted between object list and a spreadsheet will be revised from version to version, we recommend you use a spreadsheet as an intermediate placeholder to see which attributes are available before copying between windPRO versions. Simply copy the objects of interest from the object list to the spreadsheet, see which attributes are included and thereby identify what can be “pasted back” to windPRO.

2.5.4.5 List of Object IDs

When copying coordinates into windPRO, it is possible to assign the object type.
From windPRO 2.8 the object ID type scheme was changed to the below IDs:

Object	Type ID
	NewWTG
	ExistWTG
	WTGnet

Object	Type ID
	Shadow
	Camera
	CtrlPoint

Object	Type ID
	SiteData
	NSA
	Shape

	WTGareas
	HCData
	HCGridObj
	AreaObj
	MeteoObjectData
	Obstacle

	?
	?
	?
	VR
	RadarObject
	Ruler

	UsrTextData28
	ExtGrid
	EGrid
	BusVar
	Transformer
	ELoad

For instance, pasting “CtrlPoint 514273 7513830” into the object list will create a Control Point at the specified coordinate location

2.5.5 BASIS calculation

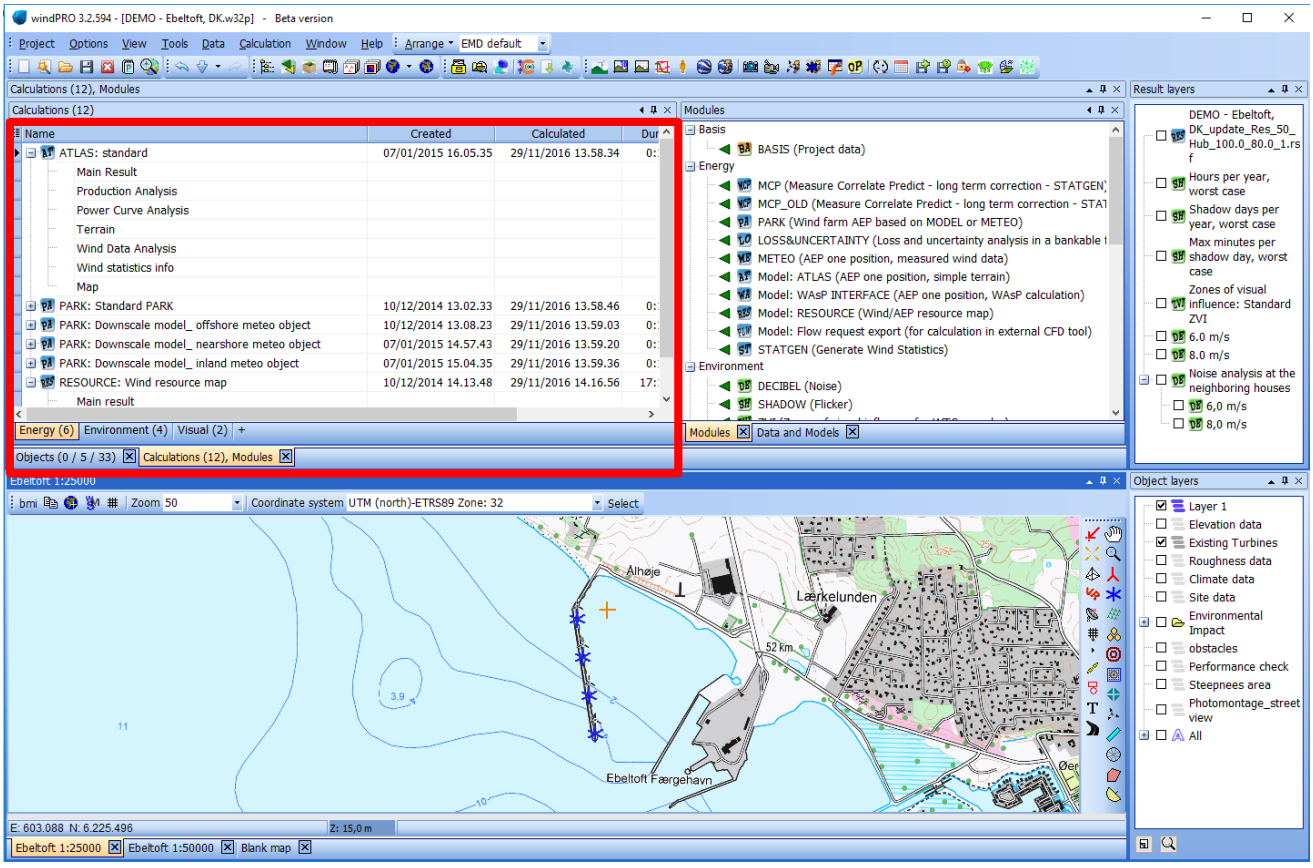
With the module windPRO BASIS alone, it’s possible to perform a so-called "BASIS-calculation". The "BASIS-calculation" does not calculate, it merely generates a complete report of the data that has been inputted, and a map with a presentation of the project. This gives for example, the potential buyer of WTGs the opportunity to work with different project layouts using the windPRO program at a very favorable price and the ability to forward the information (e.g. a windPRO export file) to different manufacturers for calculations and quotations.

After a calculation, you can copy the calculation (by right-clicking on the report header). Then a copy of the report and all calculation settings is made. If you later change the WTG layout on the map, you can recalculate the copied calculation, so you now have two calculation reports with same specifications, but with different WTG layouts so that the two sets of calculations are identical except for the layout.

2.5.6 Printing – general tips and setup

Calculation output (in the form of reports) is stored in windPRO. If a printout of an earlier calculation is needed, you just have to open the project in question and print out the required reports without having to rerun the calculations.

The output is arranged in a tree structure. It gives you a good overview of the calculations carried out. This tree structure is shown on the calculation icon button.

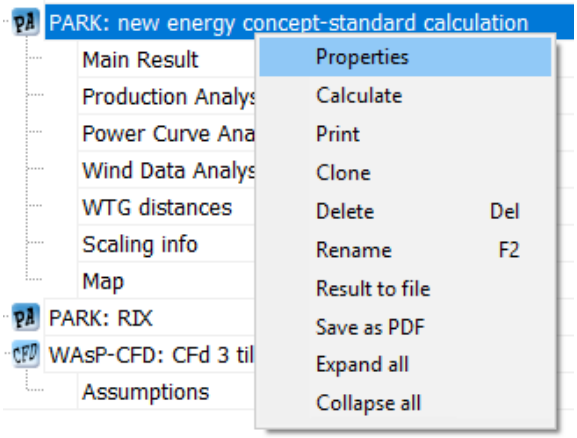


When a calculation has finished, the available reports that can be printed will be shown on in the Calculation window (here 12 in the top left corner). Clicking the small “+” button creates a new sub-tab and calculations can be drag-and-dropped from one sub-tab to another. The individual sub-tabs can also be re-arranged.

There will be info columns showing when calculation was created, last calculated, the duration and with which windPRO version. The size in MB show how much space the given calculation takes in the project file. Having a larger project file slows down Save/Open, so it is worth deleting large calculations that are no longer required.

A sub-level report will automatically pop up on the screen if you double-click on a sub-level report name (e.g. “Main Result”). The sub-level report has its own right-click options, where you can define

report details. When you right-click on the calculation header or on one of the calculation reports, you get access to this menu:



Print gives access to set up all report features that can be modified.

Clone makes a copy of the calculation, so it is easy to calculate another turbine layout with exactly the same settings – just the turbine selection shall be changed.

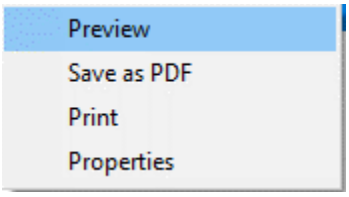
Result to file allows for saving some results in other formats, e.g. copy to clipboard and then paste to Excel or save results as text files. Some graphic outputs, like noise isolines, can be saved as ESRI Shape files.

The line with the calculation name (in this case PARK), is the "header" of the calculations report. The name the user gives the calculation (in this case "new energy concept…"), also appears in the header. The reports follow subsequently.

To view setup or print the reports, there are several options described as follows:

2.5.6.1 Print a single report with default settings/preview

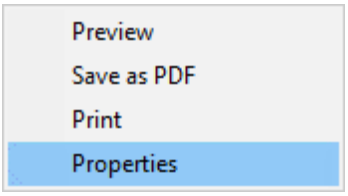
To print a single report, select report (click on report) and right-click and select **Print** from following menu:



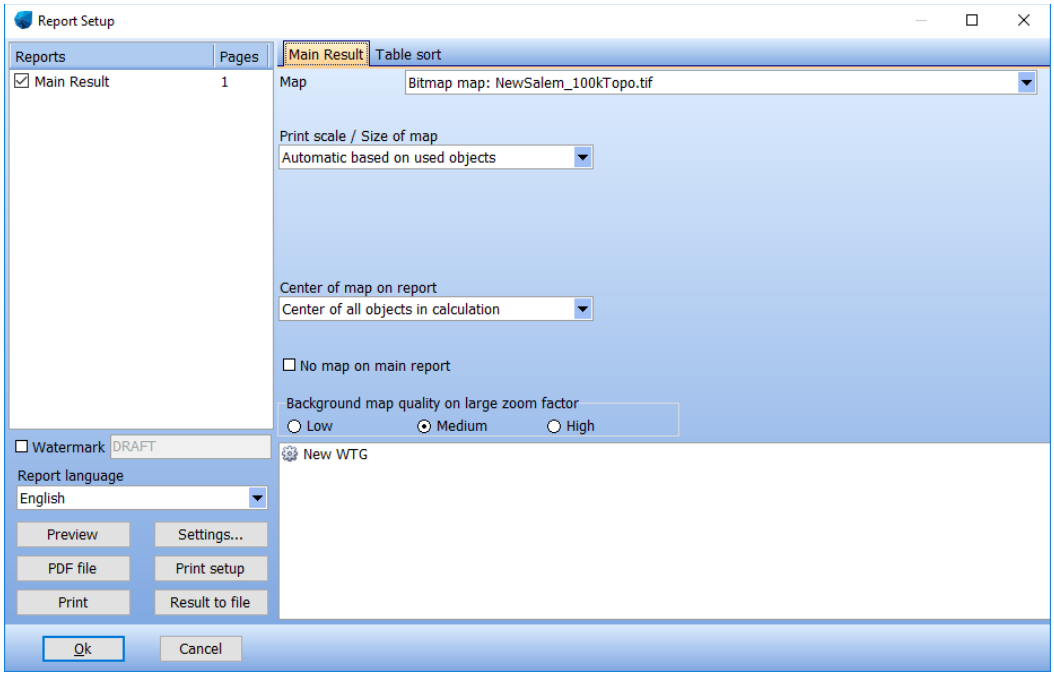
To preview a single report with default settings, simply double-click on the report, e.g. on **Map** or **Main Result**. Depending on your general windPRO settings, the report preview will be shown in the built-in windPRO previewer or in your PDF reader (see Options).

2.5.6.2 Setup of a single report

Right-click on report name and select Properties from the following menu:



The following window appears depending on which report you have selected.



In the right part of the window, you get different tab sheets where individual settings can be applied to the report. In the left part are following important features:

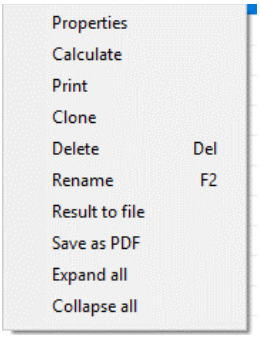
Result to file - in more reports; the calculation results can be saved to a file or to the clipboard for further processing in e.g. spreadsheet tools.

Report language – Different report languages can be selected (if license is purchased)

Settings – The report setup can be saved and used for other reports. Also, the report language selection can be saved so it's used in all calculations until windPRO is shut down. The next time windPRO is started, the original language will reappear as a default unless **Use as default** is checked.

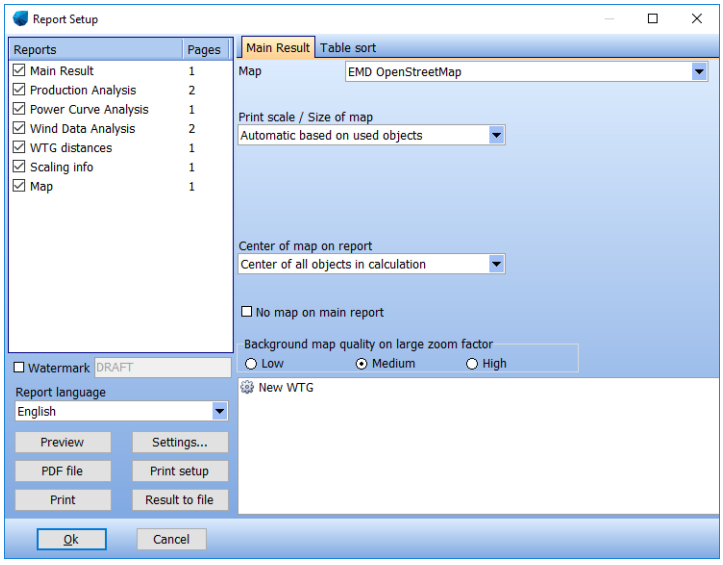
2.5.6.3 Print all reports, define reports and settings, symbol scaling, etc.

To print all reports or to set up a complete calculation report right-click on the header and select **Print** as shown in the menu.



Note: With the **Rename** function you can change the calculation name and the description without recalculating. In the case of a PARK calculation, where a simple gross-to-net reduction has been applied, this can be amended using the Rename function without the need to re-calculate.

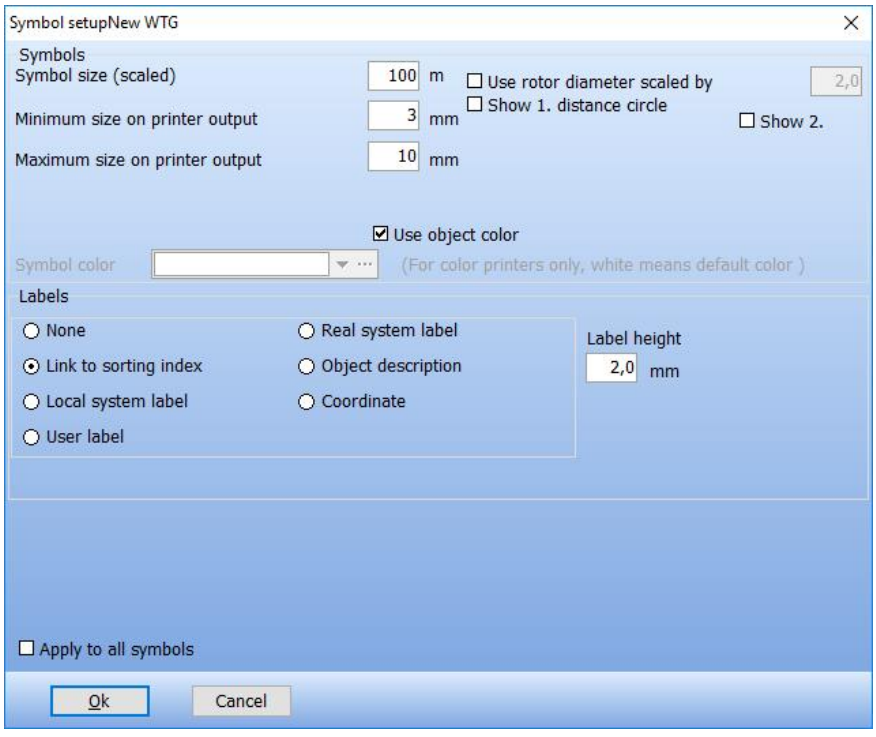
When selecting **Print**, the Report Setup menu appears.



On the left side you can select the different parts of the report you want to print, and on the right side you can set up individual parameters, depending upon which report is selected.

In the **Map** report, you can define which part of the map to print and which objects are to be included.

By clicking on the button , you can define the appearance of the objects individually in the different reports.



2.5.6.4 Sorting the objects by user label etc.

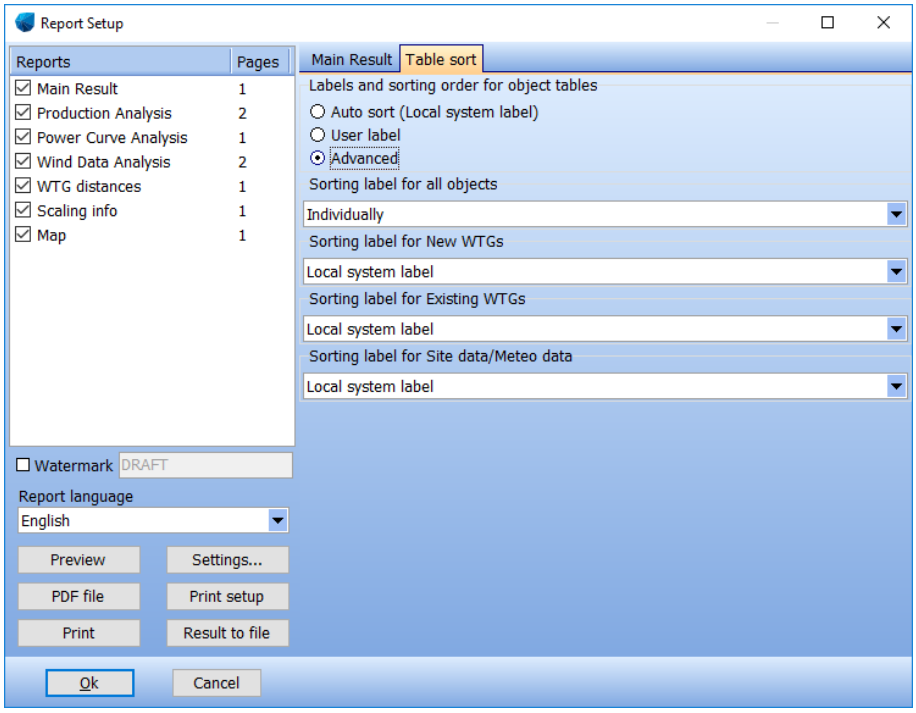
Objects can be sorted by user label or other labels.
Default objects listed in reports are sorted by object system label, but are numbered after a local system label (where objects are numbered 1, 2, 3…or a, b, c…). This option is called “Auto sort” (Local system label).

Selecting to sort by “User label”, you specify the label on the print (by supplying the objects user label) and the objects are then sorted by that user label (numerically or alphabetically).

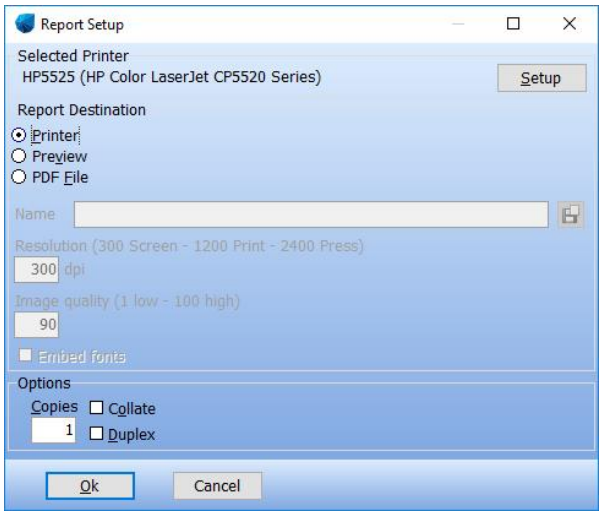
Lastly the "Advanced" option allows you to use the windPRO-assigned system label in printouts, in which case you always have the same label assigned to the same object, regardless of which objects

have been inserted or deleted. In “Advanced”, you can chose different sorting options for different types of objects.

This feature is found under the Tab Sheet **Table sort**.



2.5.6.5 Printer setup

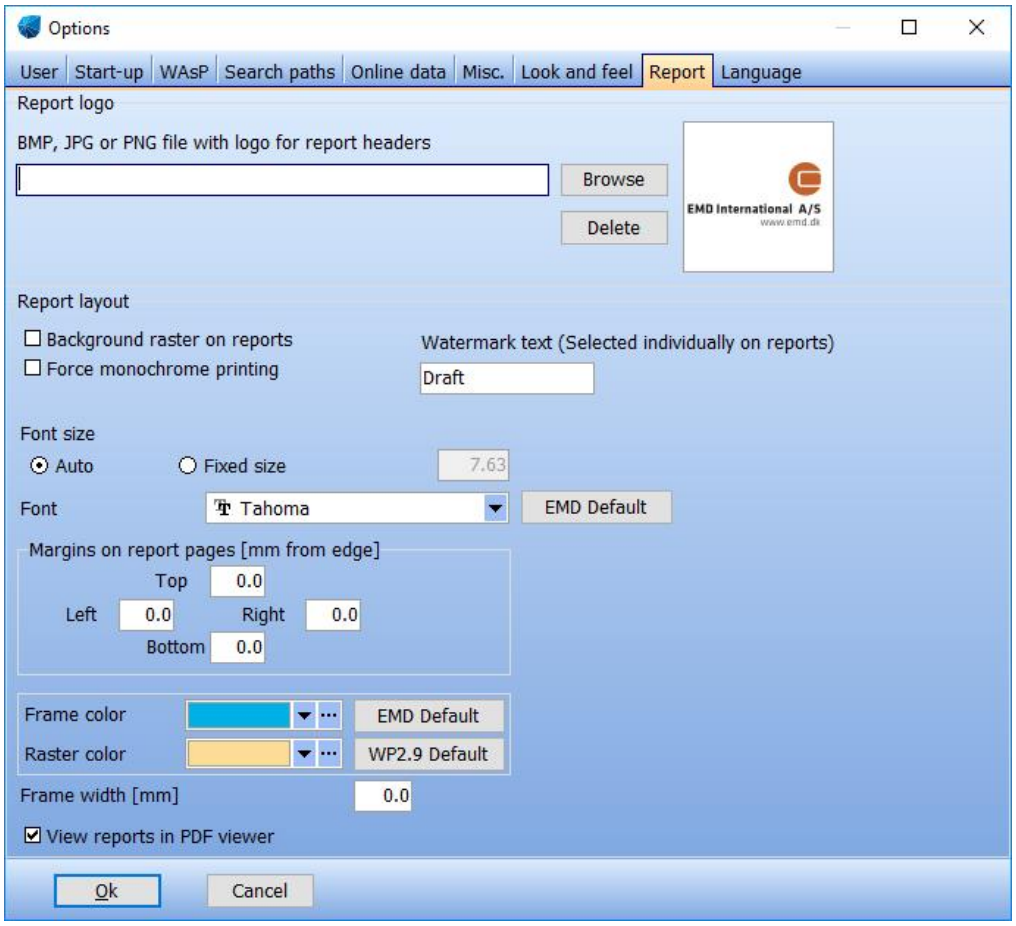


Click on **Print** to select a printer or to specify the printer setup. Depending on your printer, you can adjust the print-out by clicking **Setup**.

If you want to output a standard file type e.g. for attaching results to an e-mail, choose **Preview**. From the Preview window you can save reports as standard PDF documents. You do not need to have Adobe Acrobat or another PDF package installed.

Note: If you want to print to a file which is not PDF, you must have an appropriate printer driver installed. For example, you would need a Postscript printer driver to produce a postscript file, which many copy centers can print for you on high quality printers for inexpensive mass production.

2.5.6.6 Settings for all reports



Settings regarding all report can be adjusted in Options | Options and then select the Report tab.

From here you can add your own logo to the report headers, add a watermark text, force monochrome printing, and specify the font size and type. The margins of the page can be set and the size and colors of the frame around the report can be changed.

The checkbox **View reports in PDF viewer** lets you control if reports should open the built-in previewer in windPRO or in an external PDF viewer by default.

2.6 BASIS - The WTG Catalogue

2.6.1 Introduction to wind turbine catalogue

EMD has created a large catalogue of wind turbines for various purposes in windPRO. Over the years, more than 1000 different WTG types and variations have been collected by EMD from many sources and included in the WTG Catalogue. This Catalogue is continuously updated by EMD.

You can add your own new wind turbines to the Catalogue and you can amend the ones created by EMD with your own data (new power curves, noise data etc.). You cannot edit the data that has been supplied by EMD. You can however, make a copy of an "EMD" turbine, and use it as a template for a new user-defined WTG.

Note, that the WTG Catalogue keeps track of whether the data is created/edited by EMD or the user. In the **Source** field in WTG Explorer, there will be three possibilities:

EMD
USER
EMD-U

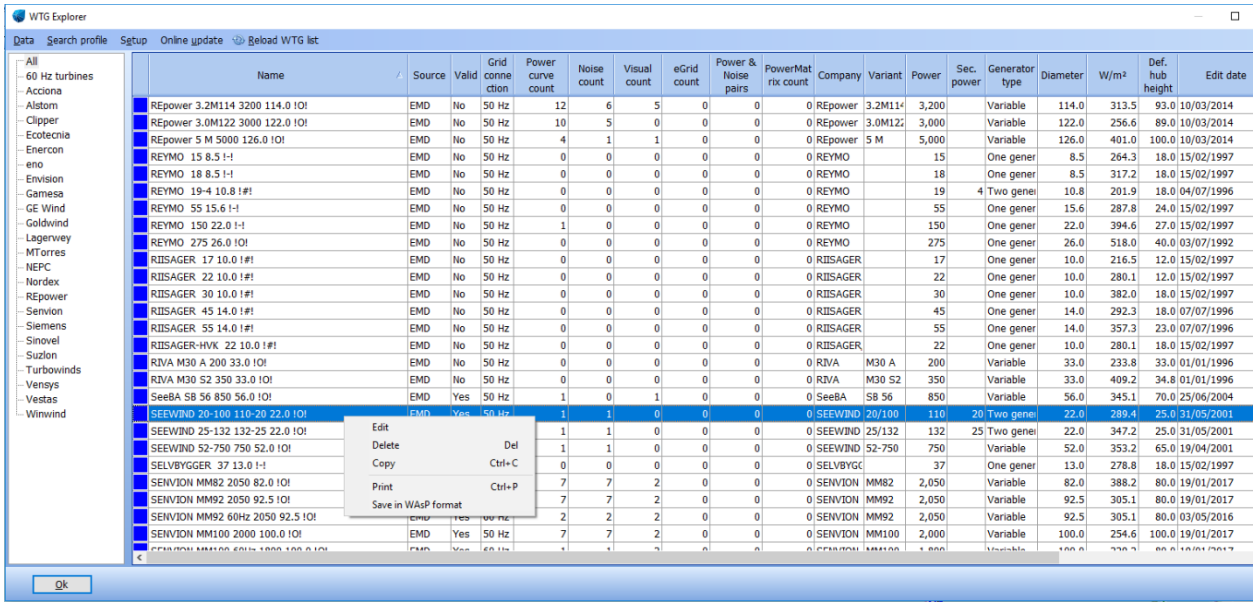
The EMD-U designation means that it's a WTG created by EMD, but the user has added some information. Depending upon the power curve used in the calculation, it could be either an EMD or a USER power curve. In the printouts of the energy calculation, it will indicate whether an EMD or a USER power curve was used.

The information registered in the Catalogue is primarily the type of information which is most important during the design phase of a project.

The Catalogue is structured such that, if a WTG is considered to be of a certain type (same manufacturer, generator-system, rotor diameter and tower type), it's stored in one file. Inside this file there can be additional power curves, noise data sets, visualization data sets, eGrid data, and different hub heights (tower heights). This is a compromise between reusing data and keeping the structure simple.

2.6.2 Invoke and Modify the WTG Catalogue

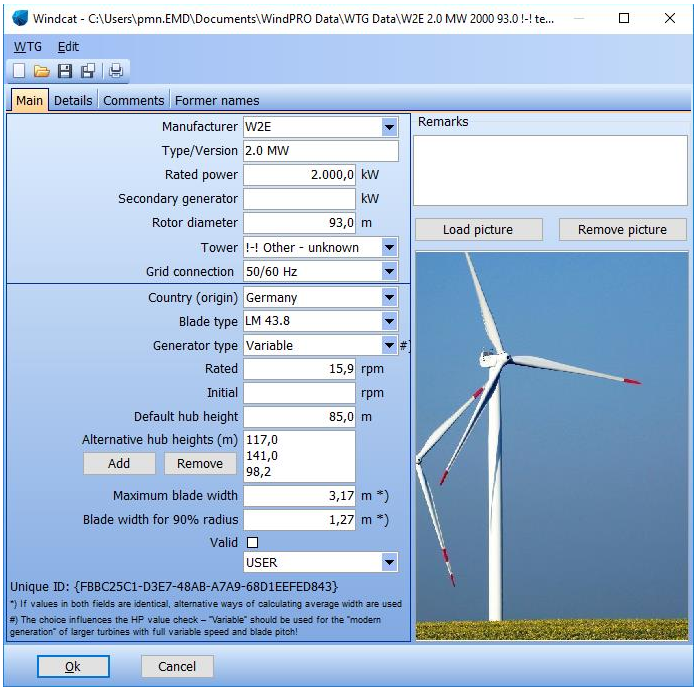
The WTG Catalogue is opened from the Tools menu by clicking on the "Archive drawer" icon. This shows you the turbines available in windPRO. If you wish to access other turbines located outside the default windPRO folder, see Search Paths for more information on search paths and search profiles.



When the Catalogue is open, a list of turbines is shown. Simply right-click or double-click on a WTG, to enter the edit menu and see more information on the turbine.

2.6.3 WTG Catalogue Tab Sheet: Main

Tab Sheet **Main** has two groups of information:

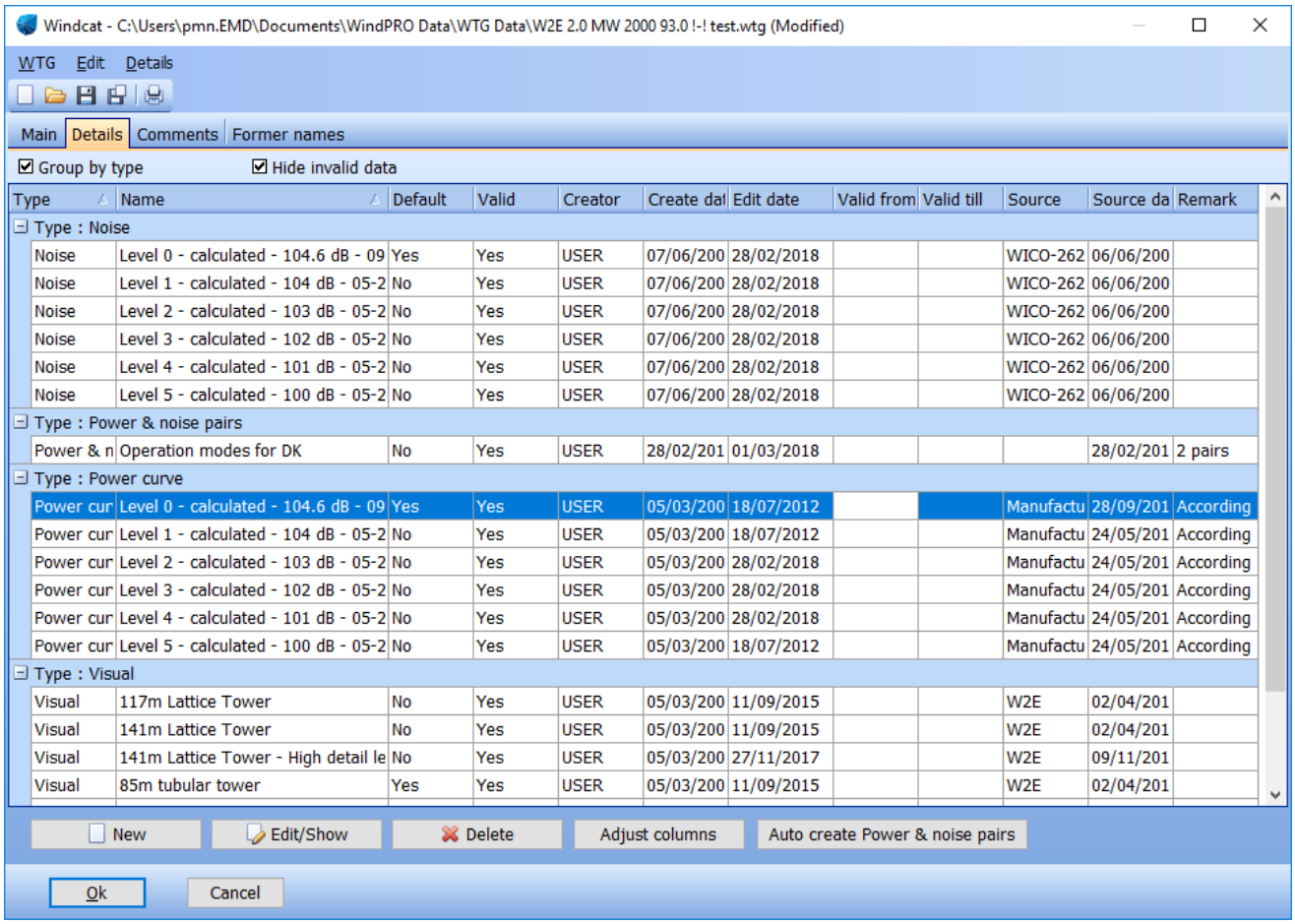


The upper section contains the unique identification and description for the turbine type, i.e.: Manufacturer, Type, kWh (large/small generator), Rotor Diameter, Hub Height and Tower Type(s). The lower section contains additional information such as: Country of Origin, Blade Type, Generator type (rpm Control), rpm, default hub height and alternative hub heights. For a SHADOW calculation, the blade width can be entered, which allows the shadow calculation to determine the distance from the turbine at which flicker may be a problem (at 20% Sun coverage). Lastly, there is a field indicating whether the WTG is valid or not (i.e. is currently available in the market), a remark field and a picture.

Note that the choice of generator type decides the HP-check, see Chapter 3 Checking the Power Curve.

The Unique ID is an internal software generated code,that makes the link to a turbine from a calculation unique, so later recalculations will always use same data. This ensures that old calculations can be reproduced, if data from EMD is used. EMD never changes data once sent out, but creates new sets of data, if specifications for a turbine has been modified.

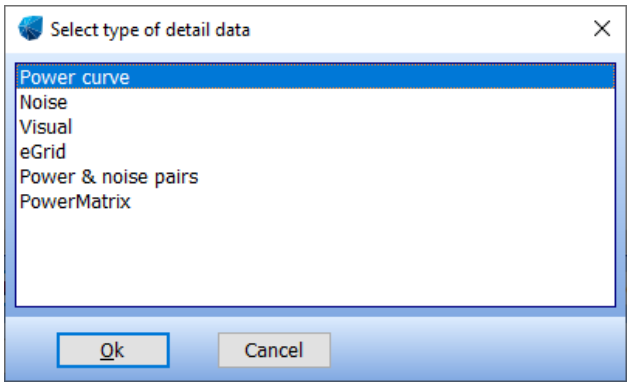
2.6.4 WTG Catalogue Tab Sheet: Details



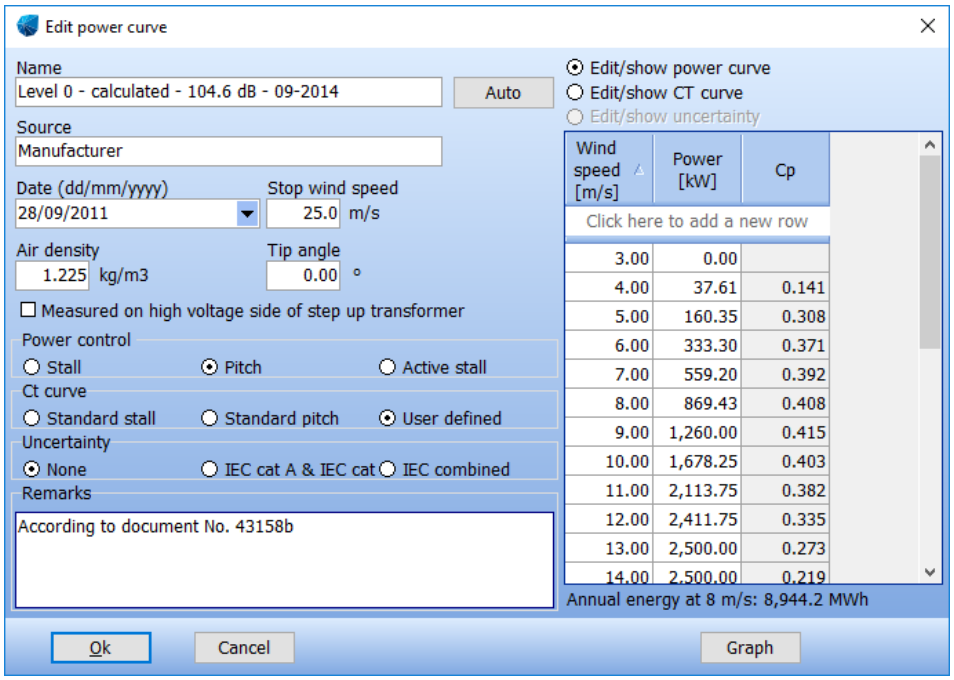
Under Tab Sheet **Details**, it's possible to add multiple sets of data belonging to different variants of the specific WTG type, different sets of power curves, noise data, visual data, or eGRID data. A special variant is the **Power & noise pairs**, which connects noise data and power curves together into operation modes. **PowerMatrix** is a new data format capable of defining power, ct and noise data as functions of multiple climate variables such as air density, turbulence and veer, all at different operation modes.

2.6.4.1 WTG Catalogue general about entering data

To add a new dataset go to the Details Tab (shown above), and click **New** and select the type of dataset you wish to add.



2.6.4.2 WTG Catalogue power curve editing



When adding a new turbine, most often you will need to include information about the turbine's power.

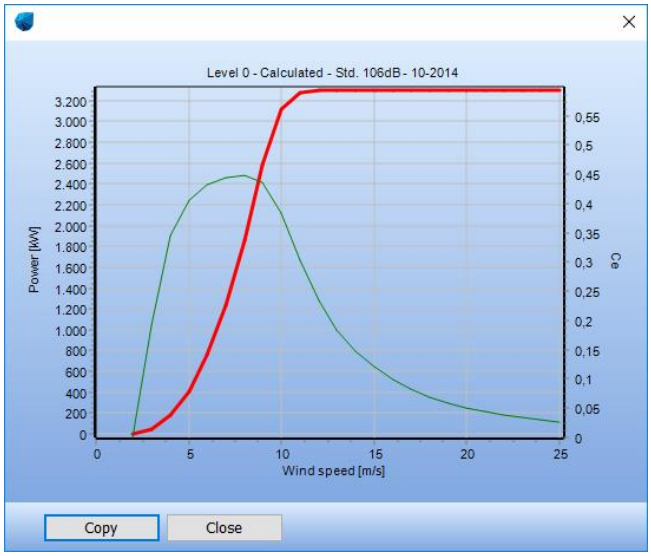
The Power curve data sheet includes information on Source, Date, Stop wind speed (Cut-out wind), Air density for the specific power curve, Power control system, Ct curve, uncertainty specification etc.

Please note when entering data in the table:
Enter first two sets of wind speed and value, then the increase in wind speed is calculated and auto filled for the remaining inputs of value. More complicated data sets should be entered in Excel, and copy - pasted into the table.

Note that the choice of power control decides the HP-check, see Chapter 3 Checking the Power Curve

Click on the **Graph** button to get a plot of the power curve and the Ce curve respectively.

The Power curves are named according to different noise levels, where "level 0" is the power curve corresponding to "no noise reduced" operation, and the different noise reduced levels follow as "level 1", "level 2", and so forth. The name of a power curve also mentions whether it has been calculated or measured (when the information is available).



NOTE on Air density:

The air density, which must be entered along with the power curve, is the one that the power curve is valid for. Below a few examples:

1) The power curve is measured at an air density of 1.1 kg/m^3 and after that, normalized to a standard air density of 1.225 kg/m^3. In this case, the standard air density of 1.225 must be entered.

2) A power curve is recalculated and entered with an air density changed from 1.225 kg/m^3 to 1.05 kg/m^3 (thin air conditions). Then the air density value of 1.05 must be entered (as well as when entering air density in the later energy calculation where used with thin air conditions). The recalculated power curve will then be saved correctly as well as used correctly on the specific site.

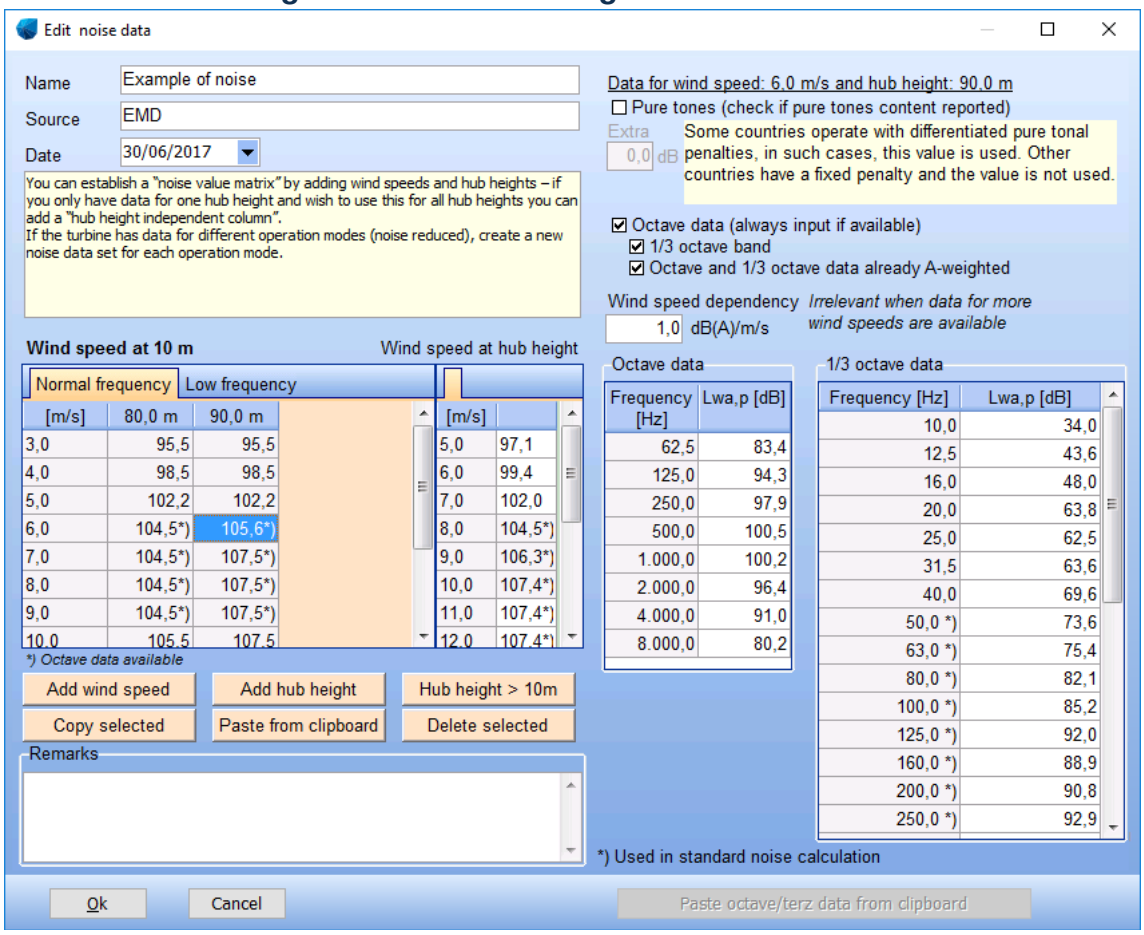
Regarding the power curve information, it should be noted that the selection of the Ct curve affects the wake loss calculations.

Uncertainty input can be as category A & B or combined, see IEC 61400-12-1 for details. The uncertainty can when entered be used in the Loss & Uncertainty module. When viewing the graph the uncertainty is shown as horizontal bars on the power curve. It is not that common to use the actual measurement uncertainty specifications, while this lead to a very high uncertainty. In “real life” the uncertainties typically are lower while the manufacturer obtains power curve measurements on many

different turbines on many different locations and thereby brings down the uncertainty by clever choice of official power curve among many curves.

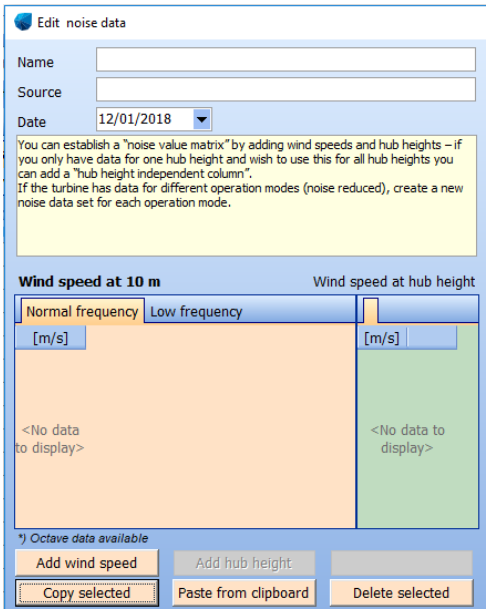
It's possible to copy the power curve to a spreadsheet. Mark an arbitrary point inside the power curve (right-click and choose Copy). In this fashion, it's possible to copy a power curve or a Ct curve to a spreadsheet. Pasting into a power curve from a spreadsheet can be performed in the same fashion.

2.6.4.3 WTG Catalogue noise data editing



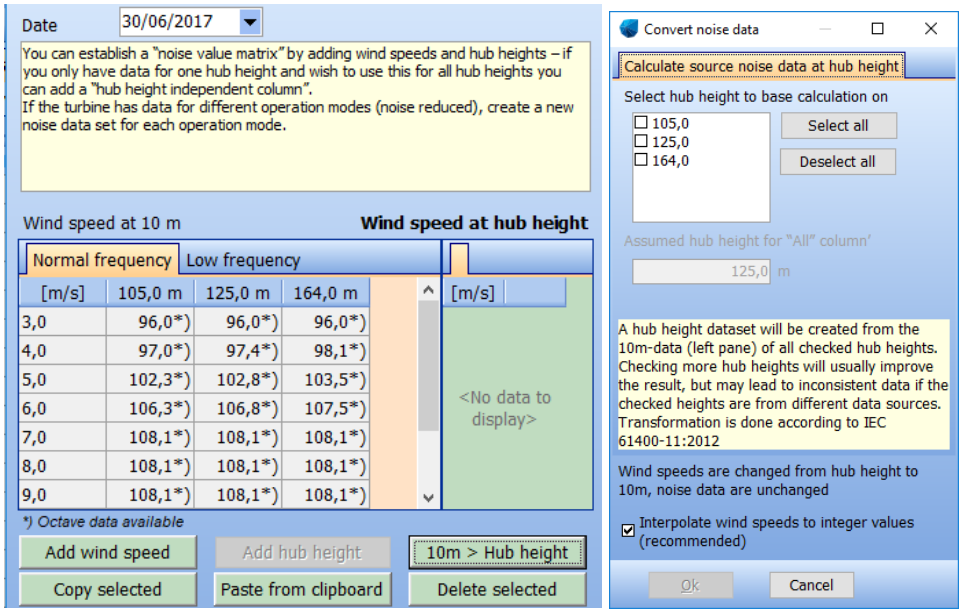
The table on the left half of the window gives the overview of all combinations of noise data for hub heights and wind speeds **at 10m height (left side) and at hub height (right side).** The table on the

right half of the window shows details for the selected data from the table on the left haft of the window. For example, the table of Octave data or ⅓ Octave data is shown when available (as marked with a ***)** in the left table). Frequencies marked with asterisks (*) are used in regular noise calculations, while those without asterisks are only used for low frequency calculations.



When creating a new noise data set, click in the orange part of the table to activate the input of noise data given for wind speed at 10m or in the green part to activate the input of data given for wind speed at hub height. Click on “Add wind speed” and “Add a hub height” or “Paste from the Clipboard”. In order to paste from the clipboard from Excel for example, the wind speed must be in column 1, the hub height in column 2 and the noise value in column 3. In the case of pasting data for wind speeds at hub height, the hub height must be defined (as a convention) in Excel as “-3” for all wind speeds.

It is also possible to enter low frequency noise data. As decreed by law in Denmark since 01.01.2012 the low frequency noise must be calculated and demands must be fulfilled. Basically, low frequency data is just a part of the ⅓ octave band data, which can be entered from 10 – 10000 Hz. The values from 10-160 Hz are used in the Danish Low Frequency Regulations. Values from 50 – 10000 Hz are used in standard noise calculations. So there is an overlap, and therefore having the complete frequency spectrum data, no additional input is needed for complying with all calculation methods. Having only data for the low frequency spectrum, 10-160 Hz, the data shall be entered with the tab **Low frequency** selected. If ⅓ octave band data are available for all frequencies, it will be the same table that is seen for 10 m and for 10m low frequency and thereby editing in the one will edit the other.



If noise data for wind speed at hub height is required but not available, it is possible to create this data on the basis of the noise data for wind speed at 10m (if available). Click in the green part of the table to make it active and press "10m > Hub height". Several hub heights can be used if they are consistent (from the same data source). The wind speed at hub height is obtained through the extrapolation of 10m wind speed with standard IEC profile (z0=0,05m). It is possible to have the table showing either the calculated wind speed along with the original noise values (option: **Keep noise data, transform wind speed**) or wind speed as integers requiring the noise data to be interpolated (option **Interpolate noise data to integer wind speed**). Rules and common practice usually require data at integer wind speed(s).

Conversely, it is also possible to create noise tables for wind speed(s) at 10m based on existing data for wind speed(s) at hub height. Click in the orange part of the table to make it active and press "Hub height > 10m".

The **name** of the data set should include level or mode, e.g. Level 0 for the standard operational mode, Level 1 for the first noise reduction mode, etc. The name could also include the "most important" noise figure, e.g. 8 m/s typical hub height value.

The source should note if it is measured or calculated – and by whom.

The name of the noise data should match with a power curve with the same name. This power curve corresponding to this noise-reduced mode of operation should be used to make the energy calculation.

There is also a “Remarks” field to allow you to enter more background information such as document references.

Detailed information:

Pure Tones

If the noise measurement report states that pure tones are observed, then the field **Pure Tones** must be marked. Pure tones will result in more restrictive requirements in the calculation models.

Octave Data

Data available as octave band values (i.e. for eight standard frequency levels), can be entered. Additionally, 1/3 octave bands can be specified as well

Frequency Data

Data available as octave band values (i.e. very detailed, given on a number of standard frequency levels), can be entered. This gives a more precise calculation and is a requirement in more models used today.

A-weighted

If the data are given as octave band levels, this information may also be given as A-weighted values (if so, it should be stated in the noise measurement report). In this case, you should mark the field **A-weighted**.

Wind speed dependency

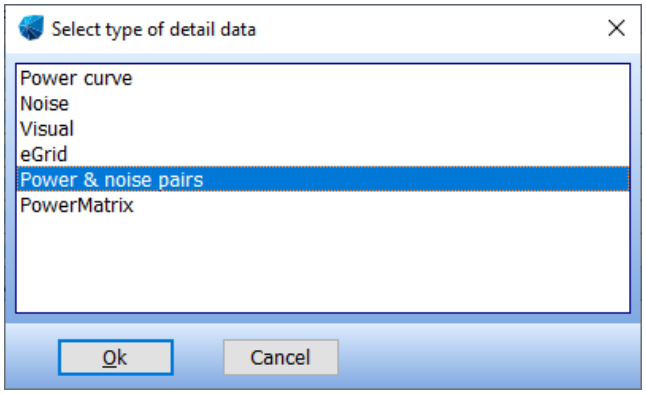
If data are missing at given wind speeds, windPRO will use the wind speed dependency factor to calculate the missing noise data. By default, it’s set to 1 dB(A)/ m/s but it can be changed by the user if measurement report show other dependency.

2.6.4.4 Power & noise pairs

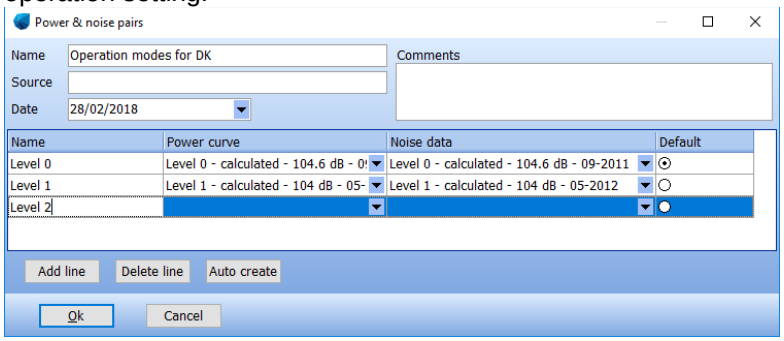
In windPRO it is possible to create different operation settings, so you can, for example, use one power curve during day and another during night. It can also be used together with the Optimizer to reduce the noise mode to adhere to noise restrictions.

In windPRO 3.2 this setup was moved from the WTG object and into the turbine in the catalogue. In the Catalogue, you already have information about power and noise data, and this information can then be paired together.

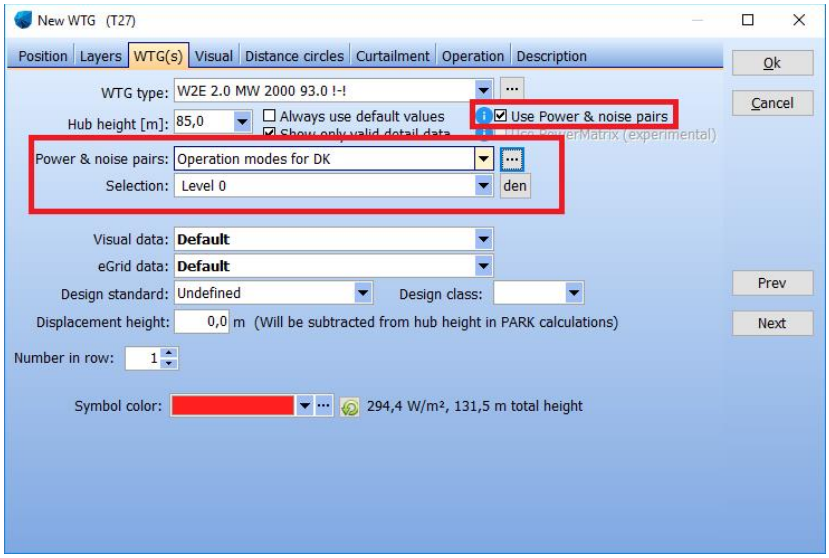
To create a pairing between Power curve data and noise data, simply add a new detail data and select the **Power & noise pairs**:



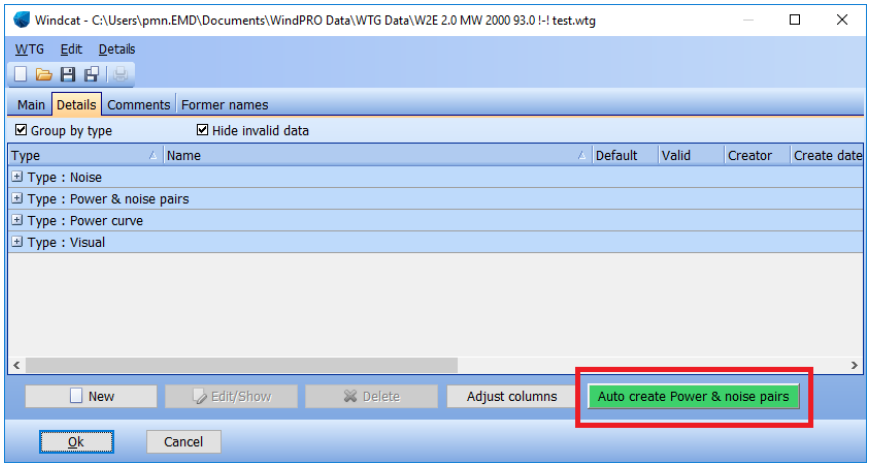
In the new window, click **Add new line** to specify which power and noise data to use for each operation setting:



Once the power and noise data has been paired together in a list, the setting can be selected in the WTG object when selecting **Use Power & noise pairs**:



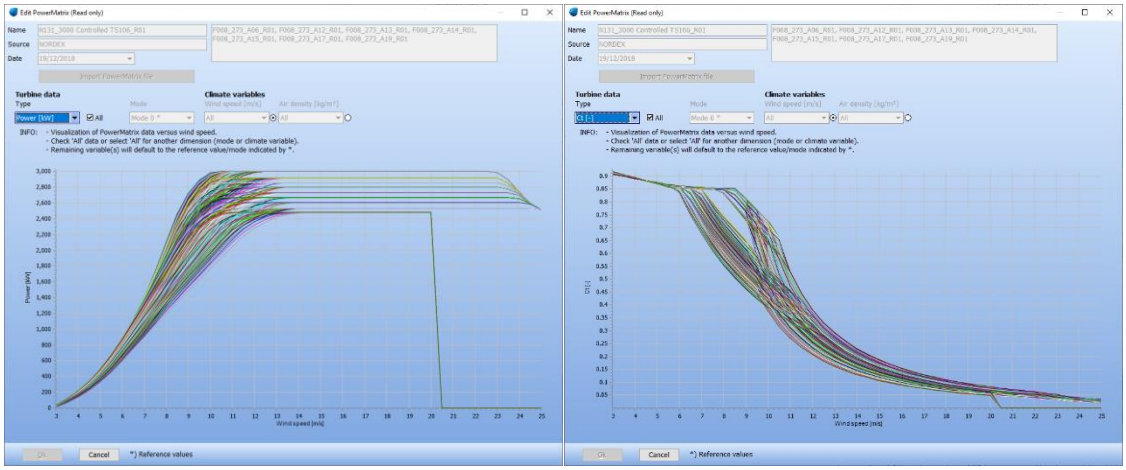
If no Power & noise pairs have been defined for a turbine you will be asked to create a list of paired power and noise data. This can be automated using the **Auto create power and noise pairs** button:



2.6.4.5 PowerMatrix

As turbines become increasingly capable at adjusting to various climate conditions, it is necessary to be able to model this behavior when planning the wind farm. PowerMatrix is a new data format containing information about the power at many climate conditions, at different operation modes, and

optionally with corresponding noise data. Since windPRO 3.3 the PowerMatrix format can be used in PARK and DECIBEL calculations using alternative operation modes at various climate conditions. For more information on the PowerMatrix format, and how to generate a PowerMatrix dataset for your turbine model, see Description of PowerMatrix format.



Above, an example of a PowerMatrix for a turbine with power and thrust data for 26 operation modes each specified at 45 wind speeds and at 17 air densities. It also contains noise information for all 26 operation modes at 10 wind speeds and 31 frequencies. This dense dataset eliminates the need for air density corrections.

2.6.4.6 WTG Catalogue visual data editing

Visualization data - describing the geometry of the turbine and its color(s)

The visualization data are divided into:

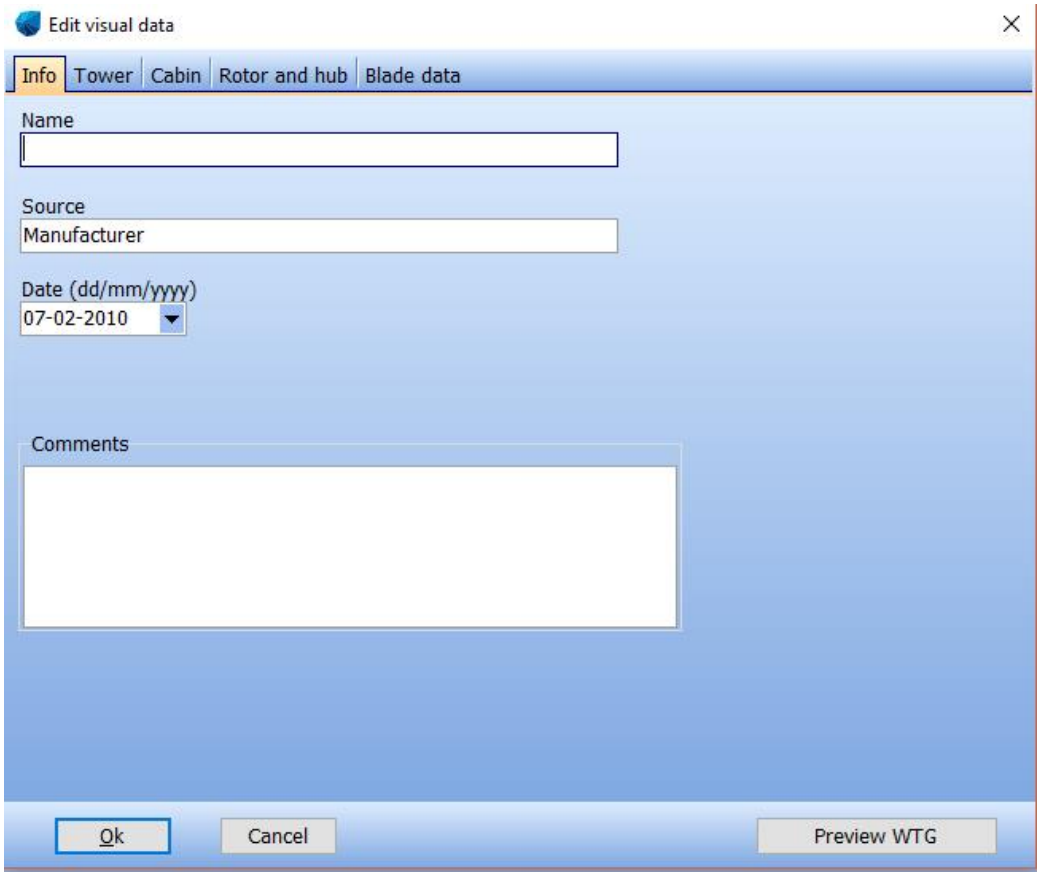
- Tower
- Nacelle
- Rotor/Hub
- Optional; Blade

A visualization of the input data is shown on a sketch during the input phase. Also, a full preview of the entire machine is available from the **Preview WTG** button.

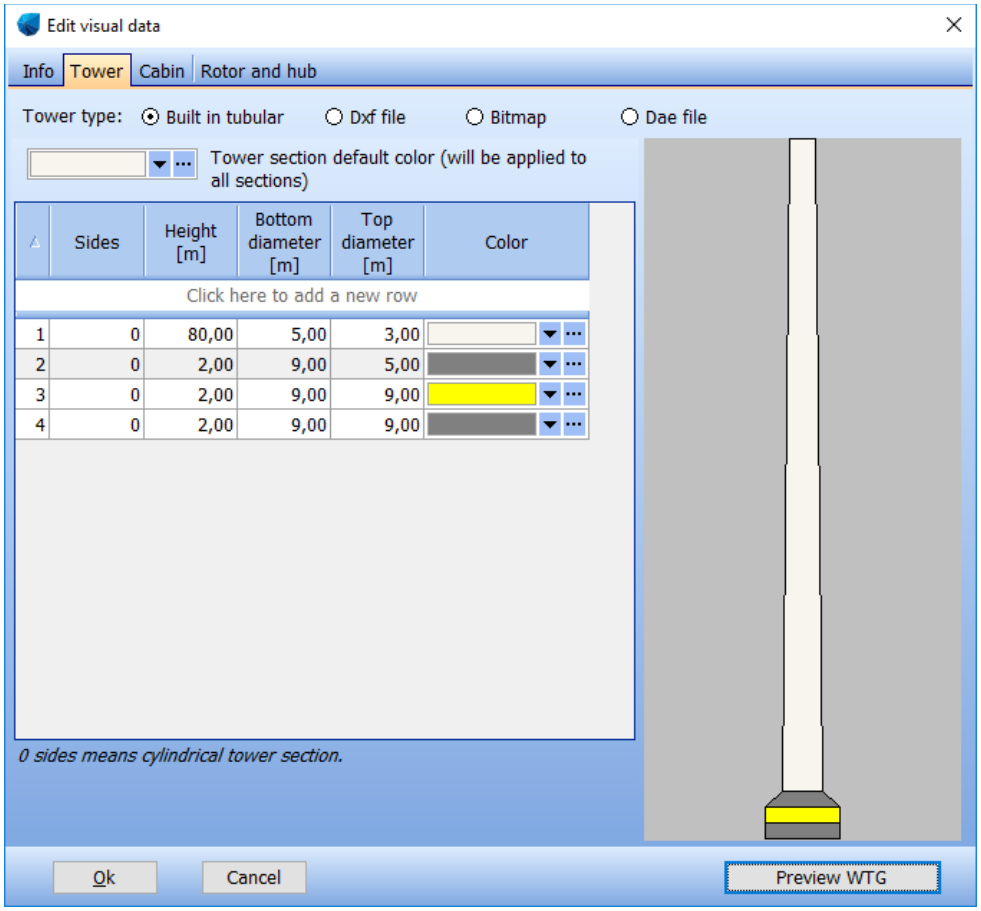
You can build both the tower and the nacelle using up to 10 sections. Note that skewed edges (different top and bottom lengths) are only allowed for the outer sections of the nacelle.

For more complex structures, it is possible to import 3D files generated by external software such as SketchUp™, in the following formats: .obj, .dae, .fbx, .skp. See this video on our YouTube channel. EMD will gradually create and upload a number of turbine nacelles of particularly complex structure in this format, upon request of the manufacturer.

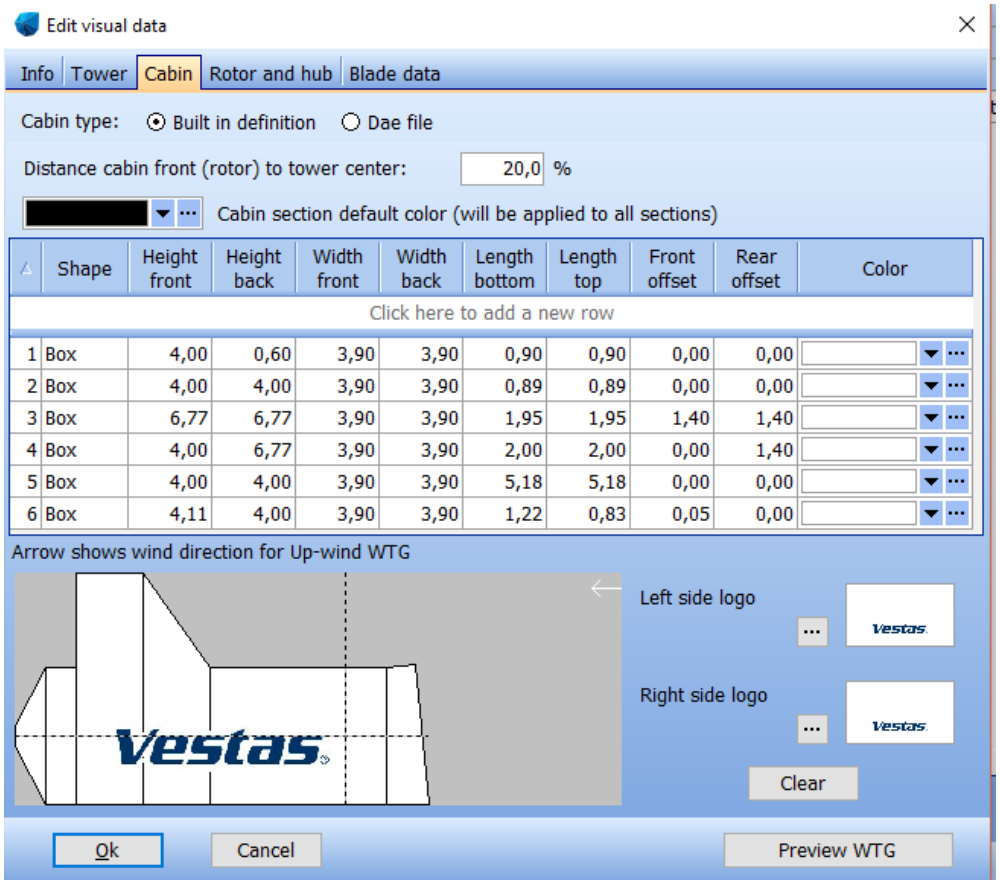
Lattice towers can be selected from a .dxf (AutoCAD) file. Some standard towers are available from the windPRO\dxf\ library. Lattice towers are automatically scaled to the correct hub height and can also be scaled to certain widths at the bottom and top of the tower.



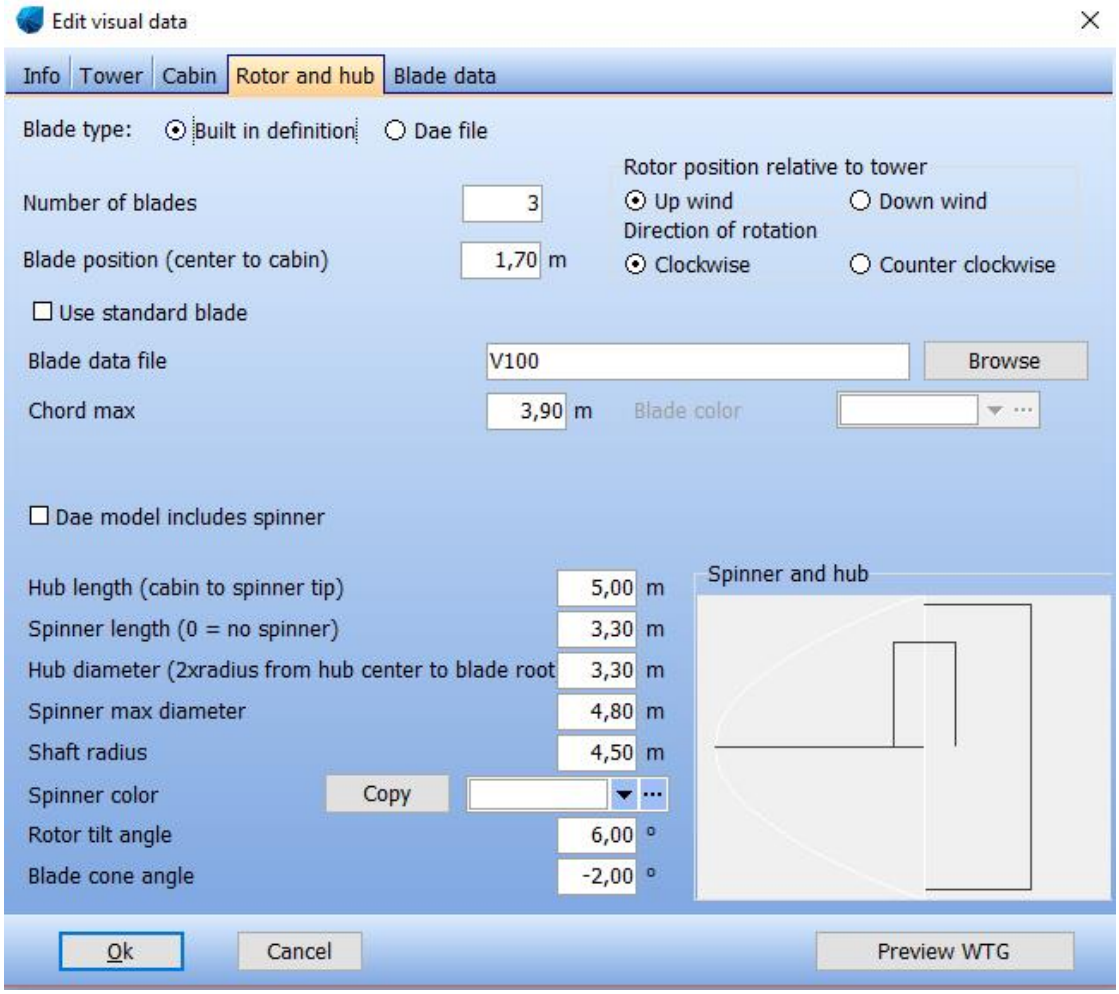
The **Info** tab sheet provides the ability to choose a specific hub height. Normally only one data set for all hub heights is provided and the software automatically stretches the tower to the hub height given in the WTG data input field. If data for more hub heights are entered, it will be possible to select the best-suited option for the given hub height when selecting the WTG.



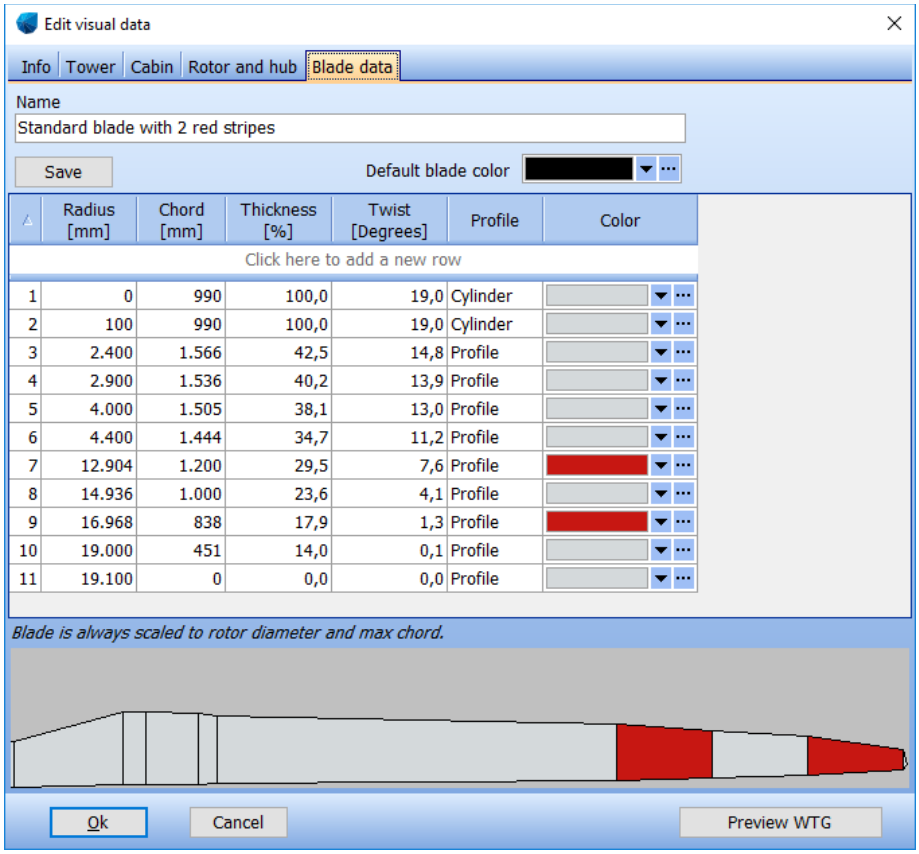
The tower can be a built-in tubular tower, dae file or a .dxf file, which allows full flexibility to specify the tower with an AutoCAD drawing. Note that the AutoCAD drawing has to be drawn following some specific rules (contact EMD to get these). A tubular tower can be fully round or with a user-specified number of faces (edges). Multiple sections can be applied (e.g. three sections as shown above). More sections are added by placing the cursor in the lower right data line and pressing the <Enter> key. Data lines can be rearranged by dragging them (right-click with the mouse on the section number column). The data lines are numbered from top to bottom of the tower.



The cabin (sometimes known as the nacelle) is designed in vertical sections. A bitmap can be attached with a logo. You have to adjust the bitmap yourself so the size and placement on the cabin is correct. The bitmap will use a square around the whole shape for positioning, so it's just a question of having the right bitmap canvas size relative to the logo size.



It's possible to choose up-wind or down-wind. This, together with the wind direction set in the Camera Object in Photomontage, determines on which side of the tower the rotor appears. Direction of rotation is only important when creating animations.

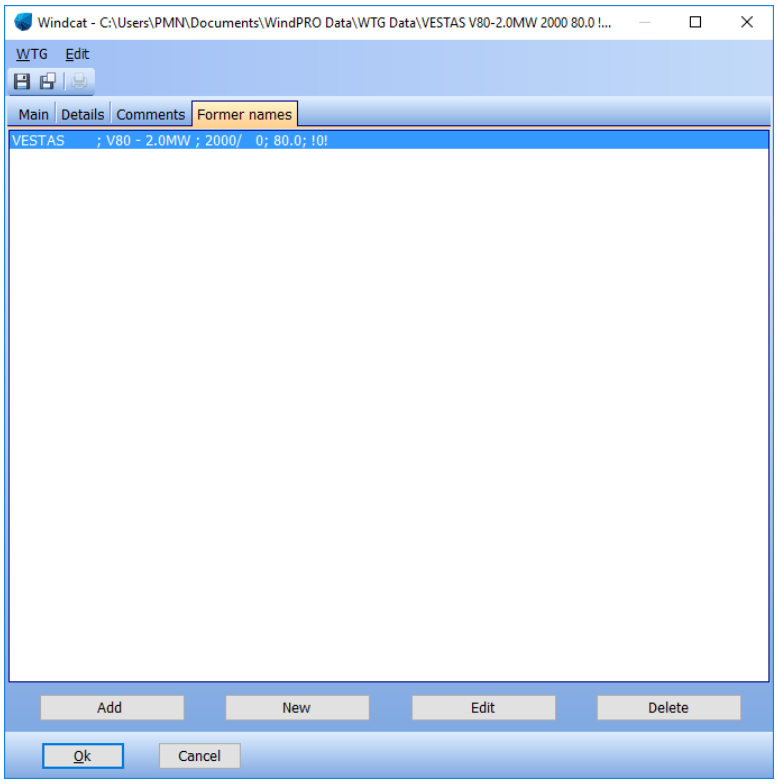


By deselecting **Use standard blade** in the previous window, you will have complete flexibility to design the blade yourself. Normally, it's only the addition of different color stripes (e.g. different blade-tip color) or by unusual blade geometry that it will be necessarily to define blade shape. Even in short distance visualization it will be difficult to see different blade shapes on a photomontage. .dae files can also be imported here.

2.6.4.7 WTG Catalogue eGRID data editing

The eGRID data of the WTG catalogue are fully described in the eGRID chapter of the Manual. Please refer to Section 10.1.4.

2.6.5 Former names



Here, former names from previous software versions can be given so that restructuring names will not affect the link from former projects to the specific WTG type.

2.6.6 Creating a new wind turbine

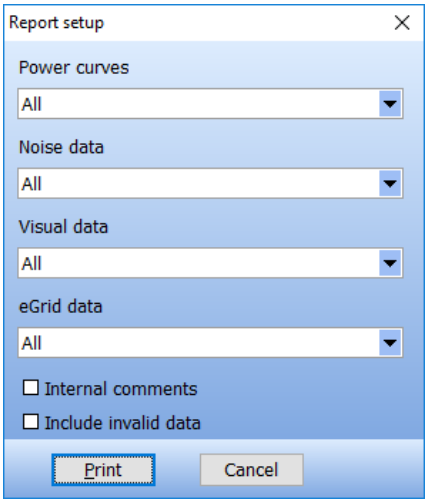
2.6.6.1 Copying and editing an existing wind turbine

It's often advantageous to use an existing turbine as a template for a new one. This can be done by opening the turbine, selecting **WTG** in the menu bar, choose **Create copy**. Now a duplicate of the turbine is ready for editing and can be saved afterwards.

When creating a turbine from scratch, you are presented with a blank input form. If a manufacturer is not listed in the “Manufacturer List”, you can create a new one under this menu item. The same applies for several other fields where you can select information from a list.

2.6.7 Printing WTGs

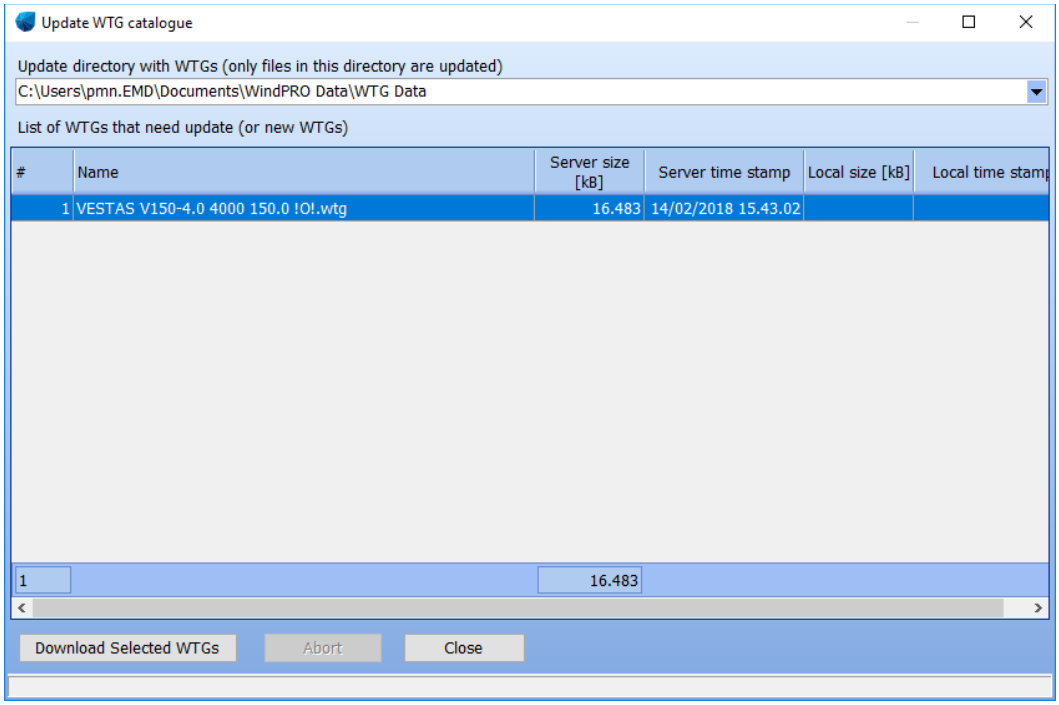
When a turbine is "open" for viewing/editing use the print option to select which parts of the data to print (see Report setup below).



When one or more WTGs are selected in the WTG Explorer, all data for each selected WTG will be printed. The print function can be selected from the WTG menu drop-down by right-clicking or simply with by pressing the <Ctrl + P> keys.

2.6.8 Update WTG catalogue

The **Updates** menu offers access to update the WTG catalogue from EMD’s server with the official wind turbine data. The wind turbines catalogue is updated regularly by EMD. The frequency of updates varies as it depends mainly on the manufacturers.



Specify the path for the folder where the wind turbine data are kept on your computer (normally in WTG Data folder, directly below the windPRO Data directory). Based upon the search path, windPRO determines which new or updated WTGs will be available. The specific WTGs to be downloaded can be selected by pressing the **Download selected** button. When an existing wind turbine is updated, the "old data" are kept so that no data is overwritten. The "old" data are then marked as not valid in the catalogue but can still be used for calculations if required. The data defined by the user are not overwritten by new files as well, since they are saved in the .uwt file.

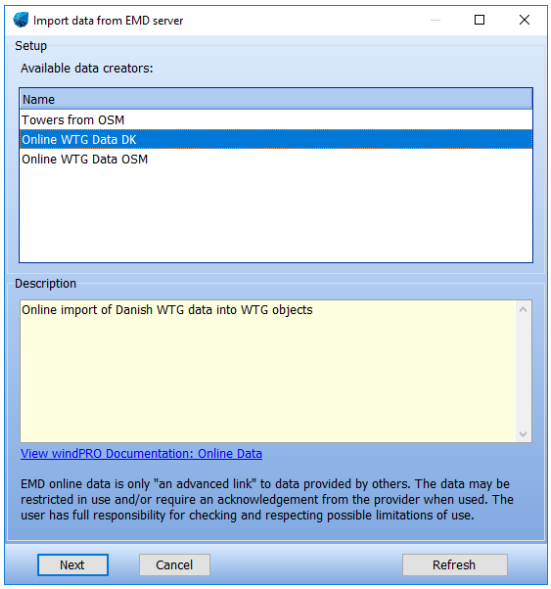
2.7 BASIS – Import of existing WTGs

2.7.1 Introduction to Import of existing WTGs

The **Import of existing WTGs** (into a project) is a very powerful function. It can be used for project design in local areas where there are existing WTGs present, as well as for planning for a larger region where existing WTGs must to be taken into consideration (e.g. for cumulative effects). The use of existing WTGs is especially powerful if information on actual energy production is available. Then, existing WTGs can have a distinct influence on the energy calculation in the new project. Also, it's often necessary in environmental calculations to include existing WTGs in order to calculate the impact on the environment not only from the new turbines, but also from all existing WTGs in the neighborhood.

2.7.2 Importing existing turbines from Online data

Via this icon it is possible to import existing WTGs and other towers from the EMD Online data server.



When there are available existing (operating) turbine data for the region, these will appear in the list above. Currently all Danish turbines are available and some other parts of the World. Selecting **Online WTG Data OSM** will import the position of existing turbines found in OpenStreetMaps. Similarly, towers, masts and chimneys can be imported using “Towers from OSM”. This is particularly useful for calibrating photomontages. In both cases, details such are heights and types are unlikely to be available.

When data are available, the radius for import can be specified and the turbines will be established as “existing WTGs” in the project.

If production data for the turbine(s) is available, it will be imported into the Existing WTG as well.

2.8 BASIS - Line Object (height, roughness and Photomontage)

2.8.1 Introduction to the Line Object

The windPRO Line Object gives you a unique visual control over the height contours or roughness lines, which are often the most important inputs for the energy production calculation. The Line Object also contributes to a significant reduction in workload when the user has to find and read Z-coordinates on traditional maps before calculating, e.g. shadow flicker, noise impact and visual impacts. Height contour lines also form the basis for computer generated 3D landscape models used for visualization.

One of the major advantages of the Line Object is that it allows the user to establish on-screen lines just by clicking with the mouse and, in the same way, it’s easy to edit existing height contour or roughness line files. The auto point mode can be activated by holding down the <Shift> key while moving the mouse. Backward deletion of points is performed by holding down the <Alt> key.

Important terms when using Line Objects with height contour lines:

DHM - Digital Height Model: Normally used for a table of (X,Y,Z) values defining discrete points on the surface. An interpolation routine such as the TIN model (see below) is needed to find the Z-values for points in between the table values.

TIN - Triangular Irregular Network: The triangle model established from the digital points (basis of the contour lines), which makes it possible to calculate Z-coordinates at any point. The TIN will usually only be calculated for a selected section of the digitized lines, as they are only needed within the area where the objects are placed. Calculation time depends on the size of the TIN-area. Due to the large number of calculations required when there is a large amount of data is present, there are very advanced features for the TIN calculation (for more information see TIN).

If you need to import gridded data, you can use the Elevation Grid data object, see Elevation Grid Object

2.8.1.1 File formats for height contour lines

windPRO can load the following file types:

windPRO format: *.wpo - Internal format optimized for speed. Height contours or roughness lines in one file. Includes the calculated TIN model, which means that the TIN calculation doesn't need to be recalculated every time you reopen a project.

WAsP MAP file: *.map - From the energy calculation program WAsP (DTU Wind Energy). Both height and roughness can be included in the same file, but when saved from windPRO, only the data from selected purpose is saved. For this reason, always make a backup of the original .map file before editing from the Line Object. Note that some binary versions may not be read from the Line Object. If this happens, open the file in the WAsP Map Editor and save it as an ASCII .map file (with the DUM* command in DOS-WAsP) before loading.

(The two formats discussed above are the only two that the windPRO Line Object can save)

AutoDesk *.dxf file: *.dxf - standard format from AutoCAD digitization).**

** Please note, that reading of .dxf files requires that certain regulations be respected when producing the .dxf file. If in doubt, please contact EMD for details.

*.xyz, .grd or .asc gridded data - grid format where you know the Z-value for each point of a 50 m x 50 m resolution area. Note these data might be more convenient to load from the elevation grid object.

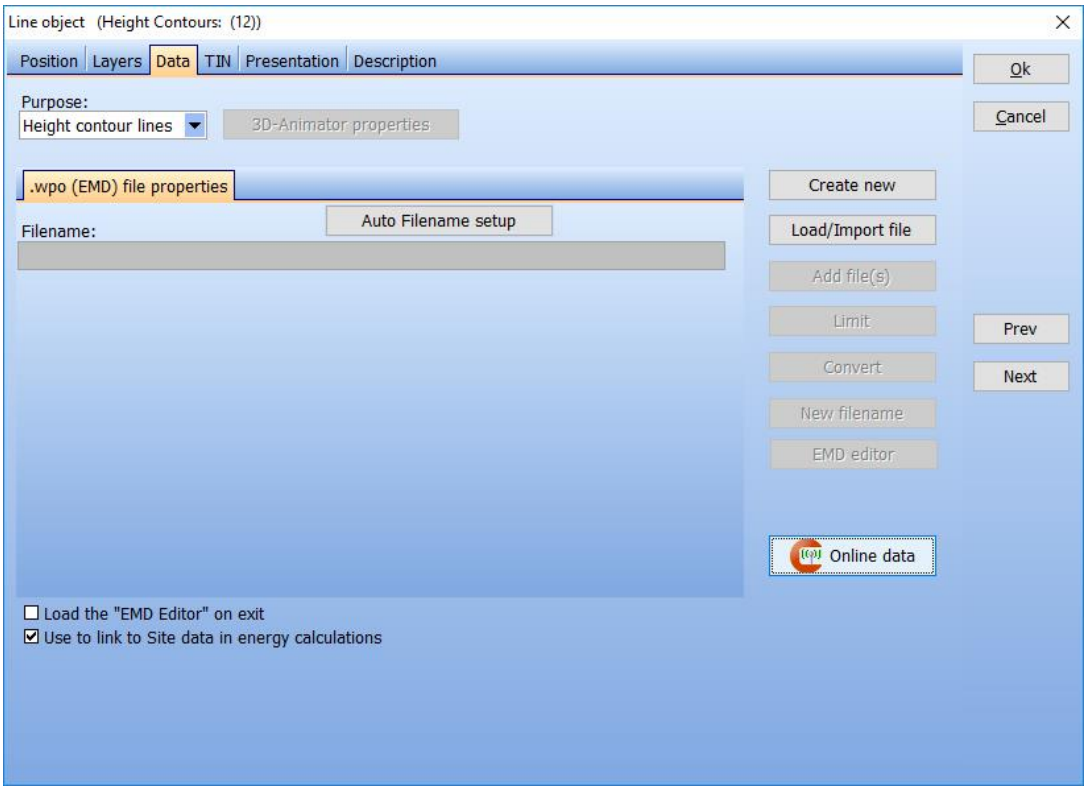
ArcView *.shp files – standard GIS (Geographical Information System) format from ESRI.

DEM files – typically used by the USGS, must be converted to *.dxf format before import.

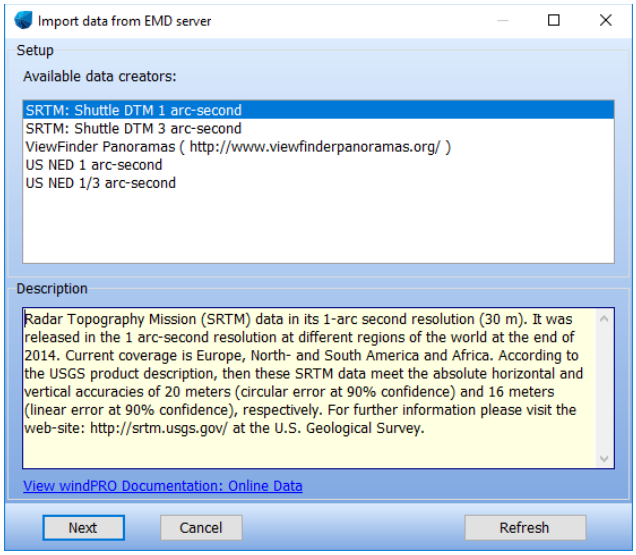
2.8.1.2 EMD Online elevation data

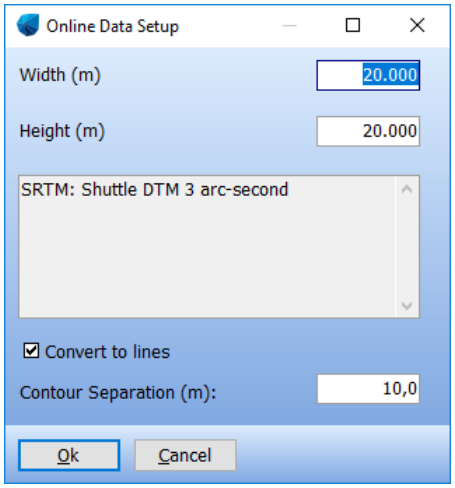
The Online data makes it very simple to establish elevation data. Simply click the “Online data” button in line object and everything works automatically. First the online service checks if there are any data sources available for the site location, and then you select the source and specify the height and width or the area you want to cover with data.

windPRO offers many datasets for elevation data, but also other purposes like wind, roughness, maps etc. For more information on the available data sets, visit help.emd.dk/mediawiki.



*To download online data simply set purpose to height contours and choose the **Online Data** button. Then select the dataset from a list of sources and specify the needed dimensions.*





For elevation data, SRTM data are available covering most of the globe. A few other data sources are available, mainly covering the non SRTM cover.

2.8.1.3 Conversion of xyz and hgt data formats to lines

Height data from .xyz and .hgt files can be inserted through the Line Object as point data, but the Elevation Grid Data Object is a more convenient data object for this. Grid data are usable in all windPRO modules. However, energy calculations based on the WAsP interface (PARK, MODEL: RESOURCE and WAsP interface) cannot handle gridded data. windPRO therefore converts the grid data internally, when using the WAsP Interface. Read more about the Elevation Grid Object in section 2.9

2.8.2 How to use the Line Object

In the current version, the Line Object can work with three types of data:

Height Contour Lines - The Line Object can import a number of different formats (see File formats for height contour lines), but lines can only be added or edited if the format is converted to the WAsP .map format or to the *.wpo format.

Roughness Lines - The Line Object can use .map or .wpo file formats. Please note that the Area Object (Section 2.9) can also be used for digitizing roughness areas, which can then be exported as

roughness lines. This is a very useful method, because it protects against crossing and inconsistent roughness lines. We recommend using this method for new projects, since the new project won't be based upon previously established .map roughness line files.

Photomontage - Used for roads or areas defined from a center line (like a tree fence

Height contours as well as roughness lines can be used together with WAsP, WAsP-CFD, OFWindCFD or WindSIM for energy calculations.

The modules DECIBEL, SHADOW and VISUAL can only use the Line Object if it contains height contour lines. With the Line Object, you can calculate triangles (TIN) between all the digitized points to allow interpolation of elevations (Z-values) to any specific location on the map within the specified TIN radius. Zones of Visual Influence (ZVI) are calculated based upon height contour lines, so for a ZVI calculation, no TIN radius is needed.

The principle is that, WTGs, noise sensitive areas, shadow recipients, etc. that are included in the calculation will automatically take their Z-coordinate (their height above sea level) from the TIN.

The calculation of shadow isolines (SHADOW module) and noise isolines using the TIN provides a more realistic calculation of the isolines by taking the variation of the terrain's elevation into account.

For visualization, you can use the TIN for the calculation of either an artificial landscape, or the visualization of a wire grid landscape. The latter is well-suited to control the camera model or to view the WTG project in proportion to the landscape without "disrupting" elements in the landscape.

2.8.3 Establishment and presentation of the Line Object

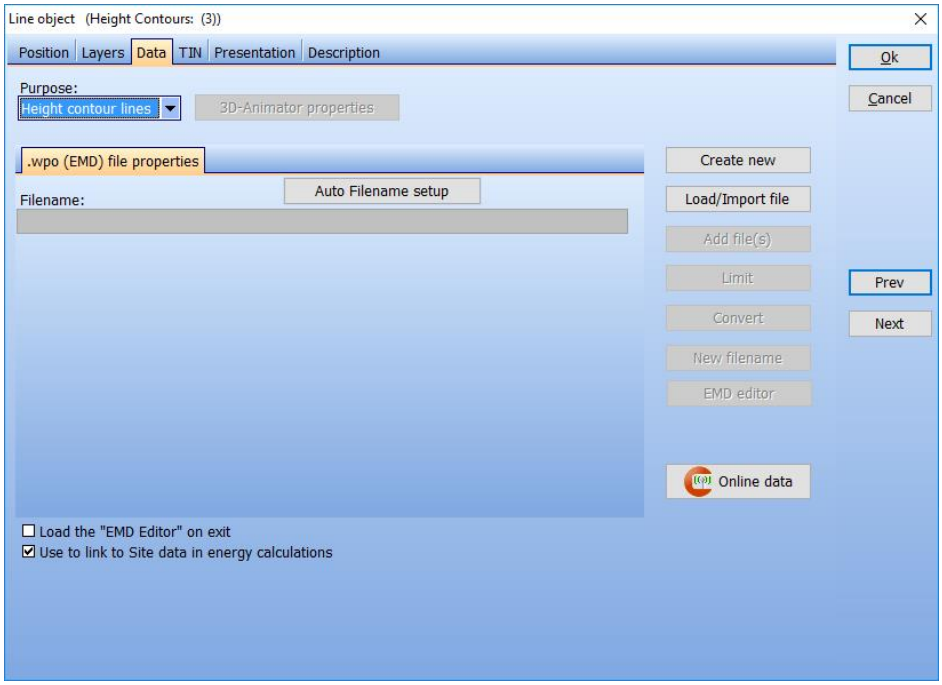
Line Objects can be edited on-screen when they are in Edit Mode. The symbols shown below indicate whether the Line Object is in Edit Mode or not. You can activate or deactivate the Edit Mode by right-clicking the object symbol on the map or by pressing the <Crtl + c> keys when an object is selected.

A Line Object which is not in Edit Mode

A Line Object which is in Edit Mode on the current map.

The same principle applies for the Area Object, WTG Area Object, and Road Object.

2.8.3.1 Tab Sheet: Data

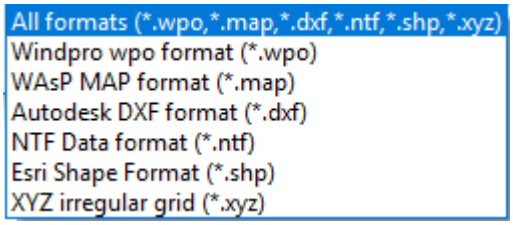


Create new - Used when starting digitizing data from scratch. First, select the input type, i.e. height contour lines, roughness or photomontage lines in the **Purpose** field.

You can choose to save data in the WAsP .map file format or in the windPRO .wpo file format. When choosing a file format, the following points should be taken into consideration:

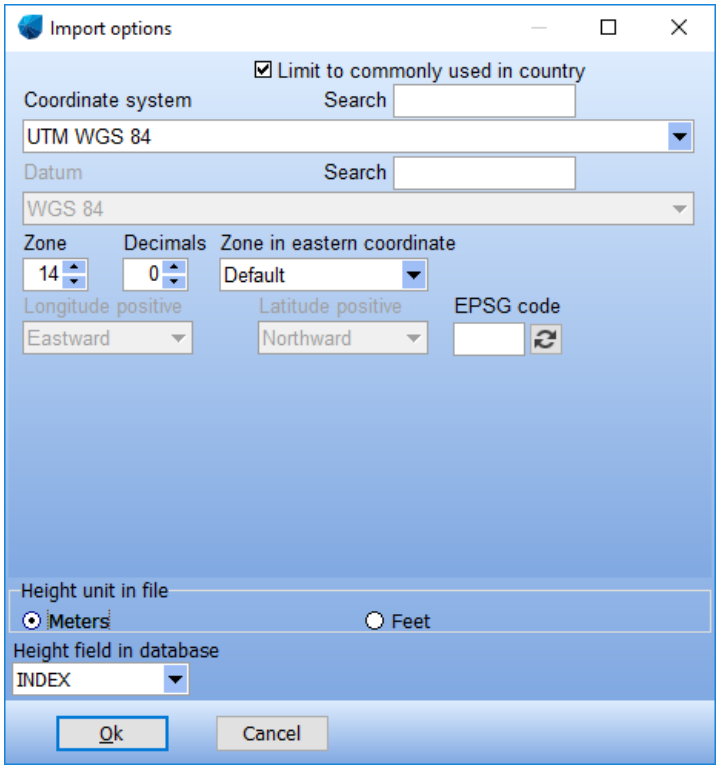
If files are large, the .wpo format is faster and for large TIN calculations (height contour lines only), the .wpo format has the advantage that the TIN is saved in the .wpo file, avoiding the need for recalculating when reopening the project. On the other hand, the .map file format has the advantage that the file can be used for stand-alone WAsP calculations (if this is relevant), and that the file can be loaded directly from the WAsP map editor (if installed and the path is set under Options). However, you can convert between these two formats at any time using the **Convert** button.

Load file - Loads an existing file with line data. Different file formats can be loaded (see File formats for height contour lines). The coordinate system in which data is given must be known. If the coordinate system is a local system (or a system unknown to windPRO) the system can be defined in “Project properties” before loading.



The supported file formats are shown in the list.

When GIS shape files with height contours are loaded, the dialog box changes as shown below:



In addition to the normal input, the projection datum (e.g. ED 50) must be entered along with the selection of which field in the shape file contains data on the elevation and the height unit used.

Add file - Used for merging additional files together in the same object. (see File formats for height contour lines).

By clicking on **New filename**, the file name of the file in which data is saved is changed and a copy of the file is made. The following corrections will only appear under the new file name.

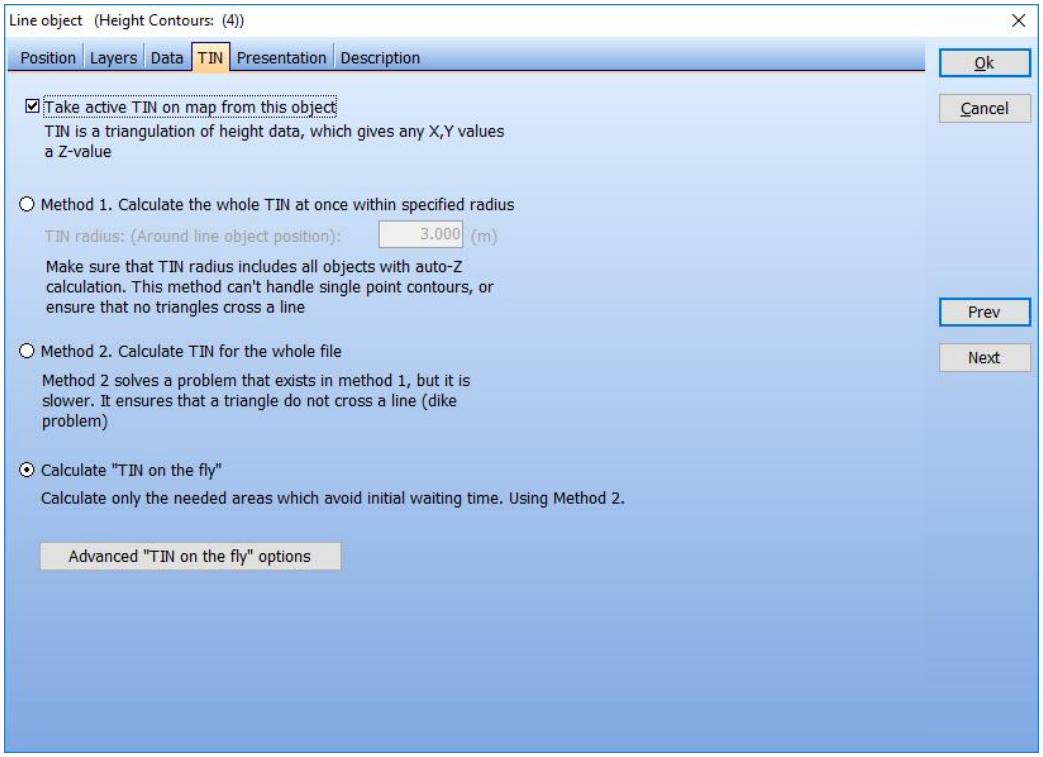
After loading large files, you may not wish to use the entire amount of data for the specific project. In order to make the file-handling process faster and to save space on disk, you can **limit** the file so that only lines with points inside a given radius will be stored. For more advanced data-limiting operations on a .map file (e.g. cut out a square, spline, etc.), the EMD editor can be used. The EMD editor can be loaded at closing the line object by checking box in the bottom of the window.

Online data is used to download elevation data from EMD server. For most of the globe SRTM data are available, for some regions other datasets. This is the fast and easy way to get elevation data, although they might not be detailed enough.

Extend data is replacing the **Online** button in Line objects where data have already been loaded. It allows extending the existing data with Online data. To extend the data with any other data (in format known by windPRO), you can use the Extend data option from the EMD editor.

By checking the box **Use to link to Site data in energy calculations** the data contained in the Line Object will be used by default in energy calculations when creating a Site Data Object.

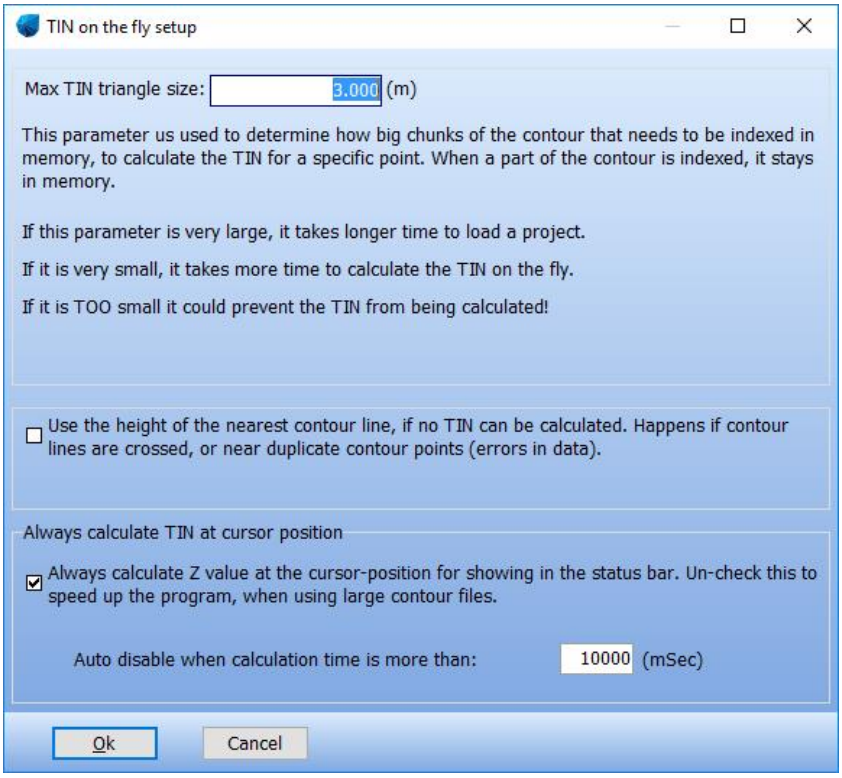
2.8.3.2 Tab Sheet: TIN



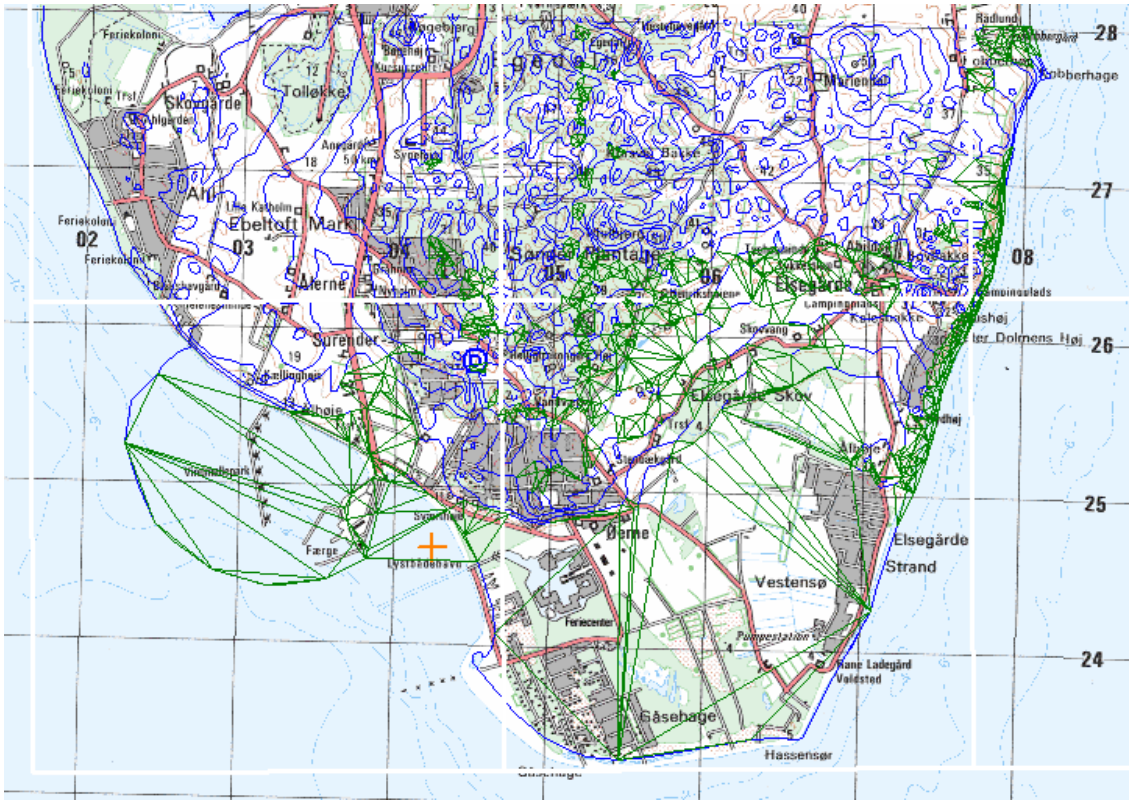
The TIN calculation can be very time-consuming. For this reason, advanced settings for the TIN calculation are available. For smaller, less complex projects with a limited amount of data, method 1 or 2 will be the best choice (typically used when a .map file is preferred). Method 1 is the fastest, but doesn't guard against crossing triangles, a problem that can cause problems, particularly at dykes, where long lines based on a few points can result in triangles across the dyke.

For larger amounts of data, the "TIN on the fly" method (used as default) is recommended. With this method, the TIN is calculated only as-needed while you work. The TIN database is built up as a background calculation without disturbing the current operation and will always have the necessary TIN values (e.g. where the object is placed). It's important to know that the "TIN on the fly" calculation will be auto-disabled if it uses too much of the computer's resources. The default setting is to auto-disable the calculation if it takes more than 1000 ms (1 second) to complete.

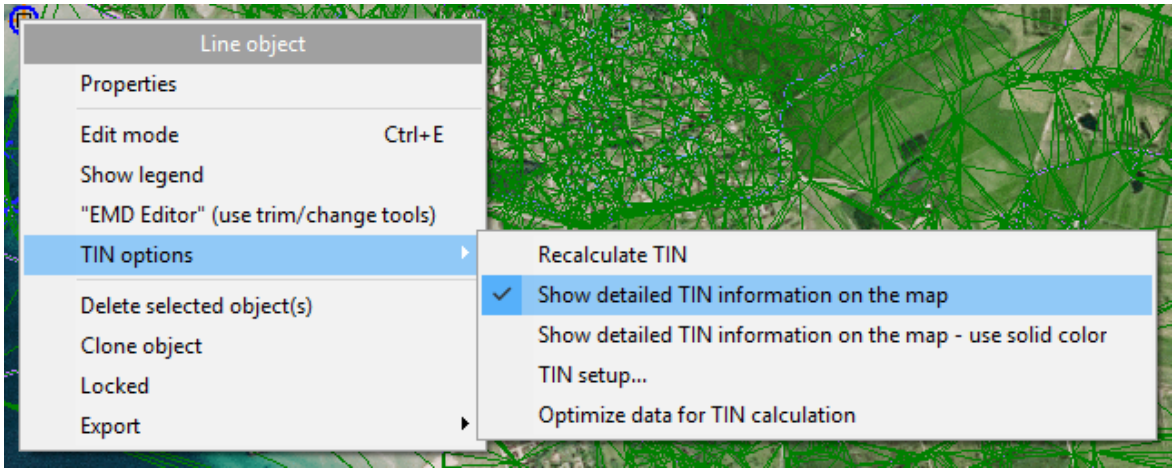
In the “Advanced “TIN on the fly” options”, the unchecked box **Always enable TIN at cursor position** in the image below indicates that “TIN on the fly” at the cursor position has been disabled. This is simply because when working with large files, the “TIN on the fly” calculation will interrupt the user too often. When the TIN is needed in a calculation, the TIN is automatically calculated for the required region. If you need the TIN for inspecting Z-levels in specific regions while working on the map, you can enable **Always enable TIN at cursor position** and perhaps increase the auto-disable time limit.



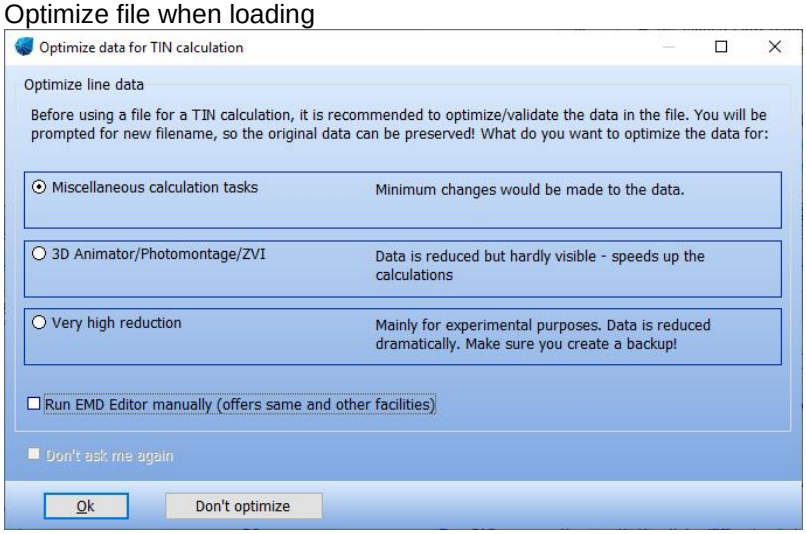
When Calculating the TIN on the fly, the model is divided into a number of squares as shown below. If there are TIN triangles larger than this grid size (white lines shown on the map), there may be problems calculating the whole region. For this reason, the **Max TIN triangle size** should be set to avoid this problem.



In the map shown above, the green lines show the TIN triangles that have been calculated so far. These can be shown by right-clicking on the Line Object or by right-clicking in the square in the bottom line where the Z-level is shown. After right-clicking, the menus as shown below will appear. Note that the option **Show detailed TIN information on the map** has been selected, which allows the green TIN triangles to be visible on the map.

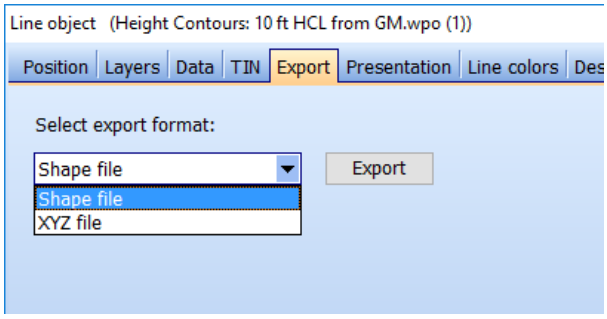


Optimize file when loading



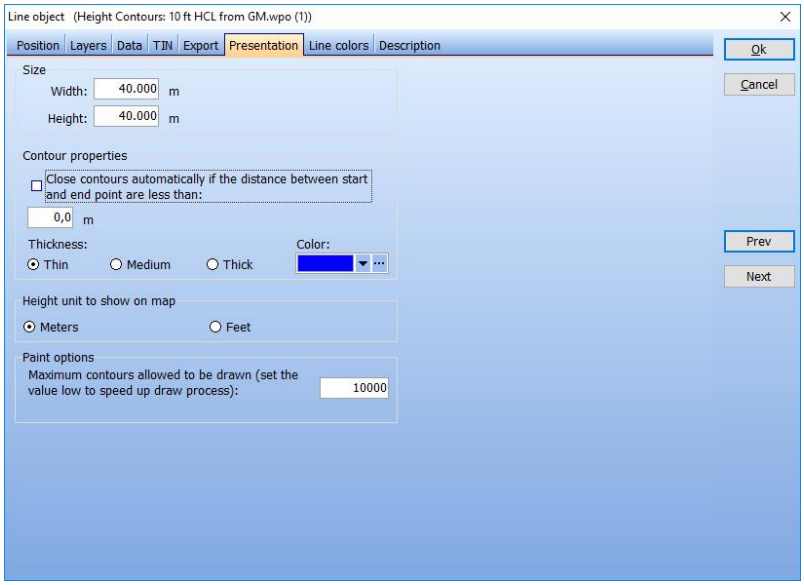
When a file is loaded, by default, an optimizer will pop up that removes unneeded points. The first of the three options can be chosen without the loss of any relevant information. Data will be lost when choosing option 2 or 3, but calculation speed will be increased. The selection should be made based upon your modeling requirements.

2.8.3.3 Tab Sheet: Export



The line object data can be exported to a shape file or an xyz file.

2.8.3.4 Tab Sheet: Presentation



On this tab sheet, you choose how much of the line data you want to see on the screen. Usually it's only necessary to limit the amount of data if you work with very large data sets. The TIN radius is the radius within which the Triangular Irregular Network is created. It's only within this radius that the Z-

coordinate is automatically calculated and an artificial landscape can be generated. The size is limited to 100000 x 100000m per object.

Due to calculation time, it may be necessary to limit the calculation of the TIN to the specific area for which you need full 3D information.

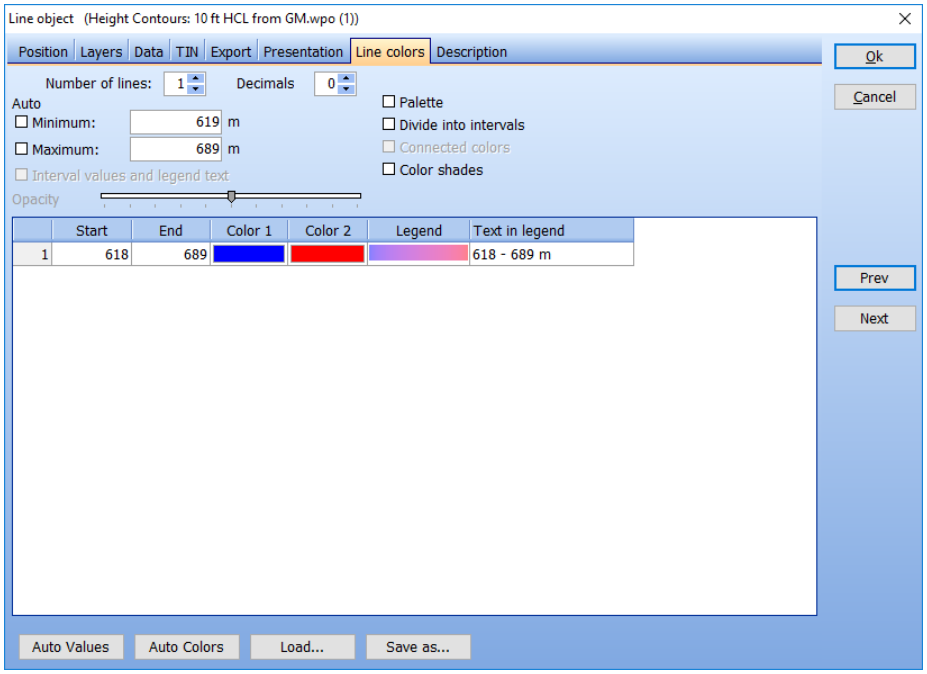
You may set the object to **Close contours automatically** for lines where two end points are positioned within the specified distance (this may improve the accuracy of the calculation and create nicer looking documentation).

You can also change the color and thickness of the isolines.

Lastly, you can choose whether the Line Object will show data in meters or feet.

Note: In windPRO, height contour data is always stored in meters, since e.g. WAsP always assumes meters when calculating. So if you accidentally end up with a .map file that is in feet, please use the WAsP map editor to convert it to meters as windPRO does not convert the height data. It only offers the ability to show and digitize in feet or meters.

2.8.3.5 Tab Sheet: Line colors

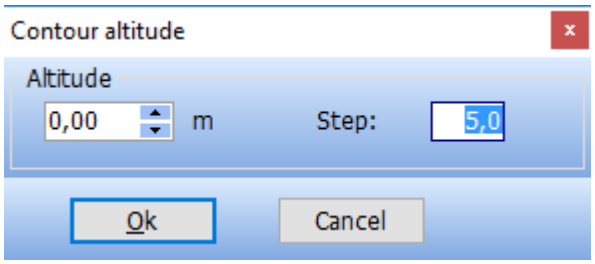


Line color definitions can be freely set. Line color definition schemes can be saved and reloaded later.

2.8.4 Digitizing and editing lines

2.8.4.1 Digitizing new lines in simple mode

When a new Line Object is placed on the background map, it will be in Edit Mode by default. Place the cursor where you want to start digitizing the first line, then right-click and select **Create new contour**. You will now be asked to enter the elevation (for height contour lines) or the roughness on the left and on the right side of the line you are going to digitize (for roughness lines). Then simply click along the line you want to digitize.



Note: In the contour elevation window, the step size when using the up/down arrows can be set in the **Step** field. This is helpful when digitizing lines of equidistant elevations.

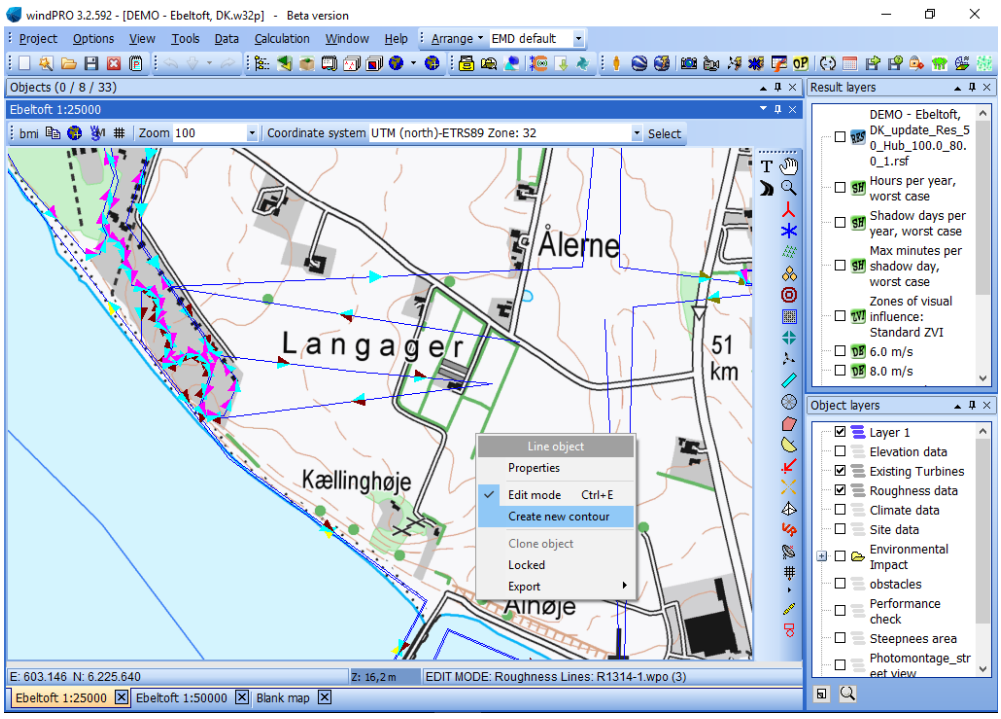
When you finish a line, you can choose between **Stop** and **Close**. If you choose **Close**, the last point will then be connected to the first one you digitized.

Note on digitizing roughness lines:
It's necessary to enter the roughness values on both the left and right side of the line in the direction of digitization. It's the user's responsibility to ensure consistency between different roughness lines. Considerable differences, for example, unintentionally crossing lines, can result in large calculation errors with no warning message given, when using WAsP. Another way to digitize roughness lines is to use the Area Object. With this method, area polygons are digitized, and lines are then exported. The export procedure makes sure that there are no consistency problems with the lines.

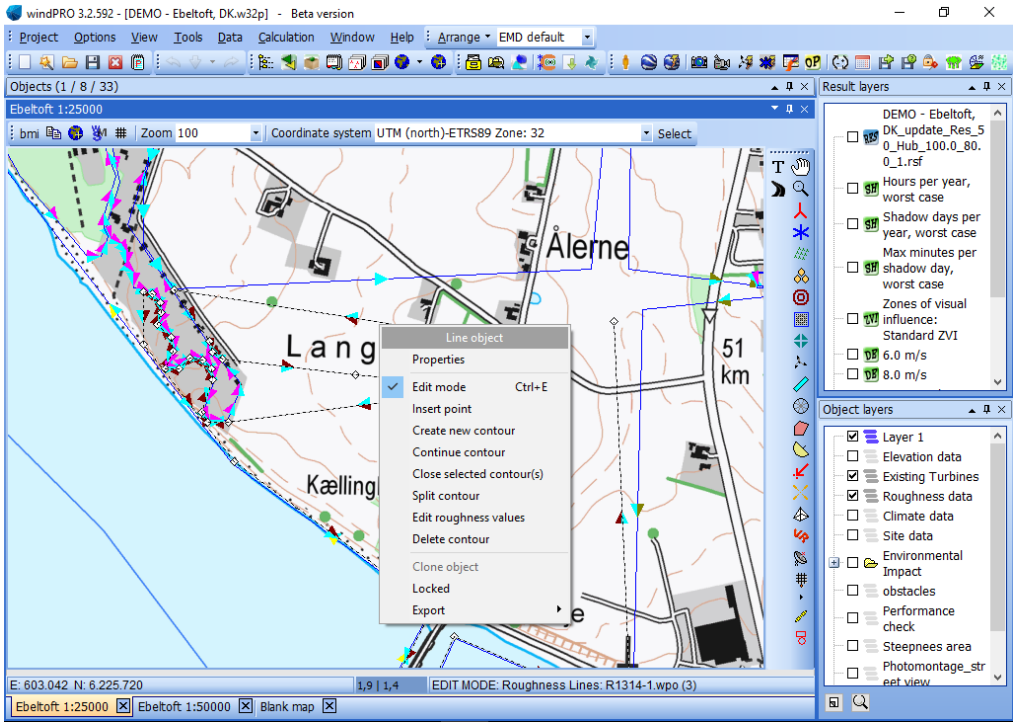
2.8.4.2 Viewing and editing existing lines

The Line Object makes it possible to import a file containing height contours on top of a background map. If the object is marked "Edit Mode", you can edit in the imported contours by clicking once on the curve to activate it. You can then drag the individual points to their correct positions by holding down

the left mouse button when the cursor is inside a point and then dragging. You can also add new points, delete points, connect lines, or add new lines. In addition, it's also possible to edit the values of the individual lines.



As shown on the map above, when right-clicking on the object, a pop-up menu appears containing several options including the **Edit Mode**. Lines cannot be edited unless the Line Object has been set to Edit Mode.

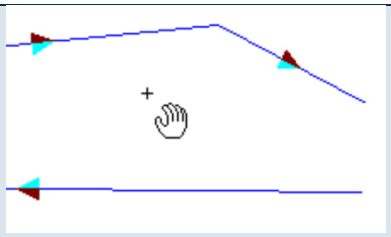
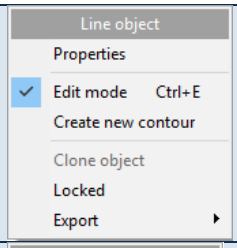
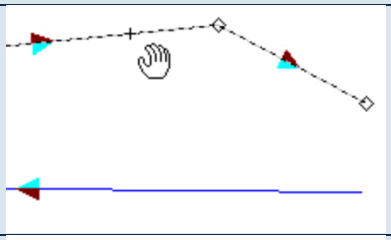
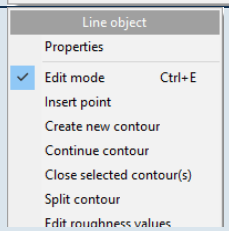
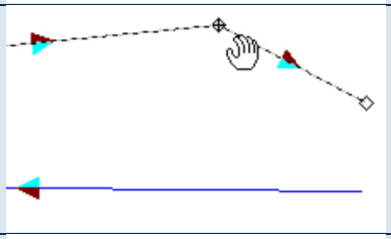
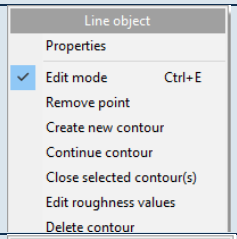
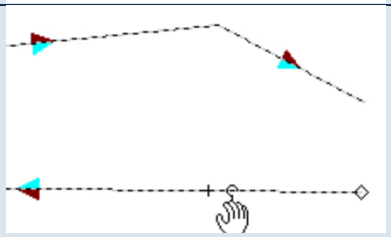
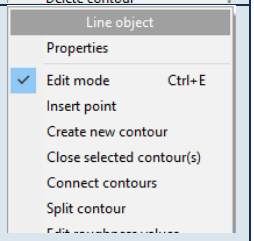


As shown above, with the Line Object in “Edit Mode”, clicking on a line will activate all the points in that line. When you hover on the height contour line, its value will be shown in the line at the bottom of the window.

After selecting a line, you can drag any point of the activated height contour lines in any direction. By holding down the Alt button, the cursor is transformed into a point eraser. Moving the cursor over highlighted points whilst holding down Alt will delete individual points. You can also right-click on the isoline to get a menu, which gives you several options for further manipulation.

Note: Different operations are available when right-clicking depending on the cursor is placed on a point or on a line between two points (see below).

Operations available	Where to right-click	Right click menu

None		
-Insert extra point on a line section -Split a line in two		
-Remove a specific point on a line		
-Connect contours / Merge lines: Hold down the <CTRL> key, and click on the two lines you wish to connect. The two closest points will be connected. If the two lines have different		

values, you will be asked to enter a value.		

Lastly, when you exit the Edit Mode, the TIN is recalculated.

2.8.4.3 Digitizing new lines without clicking

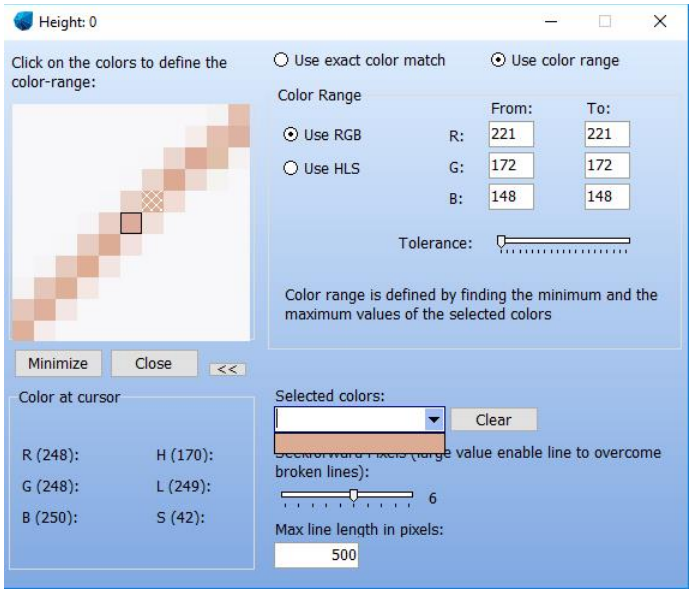
Instead of mouse clicking for each point, simply by holding down the <Shift> key, the software will do the clicking for you. When the mouse is moved while the <Shift> key is held down, the points are set automatically. This way, the lines can be drawn freehand.

If the CapsLock is on when you are in Edit Mode, then no clicking is required. Once the height or roughnesses are set, windPRO will create the line as you move the cursor, adding sufficient points to define the line (i.e. more at tight turns). Move the cursor slowly and steadily to create the lines. You can turn CapsLock on and off as you need to during this process. The Edit Mode cursor shows a "running man" when CapsLock is on.

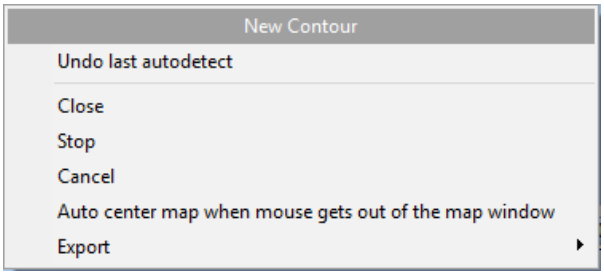
2.8.4.4 Digitizing new lines by auto-detect

The most advanced way to digitize lines is by letting the software recognize the lines on the map by color recognition. This works as follows:

When you hold down the <Shift>+<Ctrl> key, a window appears in the upper left corner. Place the cursor on a line you wish to digitize then release the <Ctrl> key and move the cursor up into the window. In the small window, click on the colors (pixels) that can be identified as having the color information of the contour lines. Diagonal cross-hatching indicates the selected pixel colors (see below).



When the relevant pixel colors have been marked, move the cursor back to the line you want to digitize, again hold down the <Ctrl> key and click on the line. windPRO will auto-detect the line until it comes to a section where it does not know how to proceed further. Click on the line to help windPRO continue in the right direction. If it finds the wrong way, simply right-click and select **Undo last autodetect** as shown below. In addition, the <Alt> key or the <Backspace> key can be used to delete the last point and thereby “move backwards”, until the digitized line is back on the track.



Then manually click a few points (release the <Ctrl> key) to help it past the critical point and press down the <Ctrl> key again to continue the auto-detect operation.

It’s important to select the right pixel colors to achieve successful auto-detection. It’s also important that the background map has relatively clean colors for the lines. If it does, then this method can be very efficient and large maps can be digitized quickly.

2.8.5 Triple junctions / Snapping to points

When you create your roughness map, it is possible to accurately and easily digitize triple-junctions. First, put your line-object in edit-mode and start digitizing a line. Hold down the < Ctrl > key and windPRO will show a 'loop' icon. Then your line/point will snap to an existing nearby point. The new point will have the exact same coordinates as the existing one. Triple-junctions are fully recognized by WAsP.

2.8.6 Save and use data from Line Object

The data file containing the lines is saved when you exit the Edit Mode. Note that if you are working on an existing file, it will be overwritten. To prevent this (if you've made changes that you don't want to save), open the file from Windows Explorer and make a copy before leaving Edit Mode.

The Energy Calculation module can use the Line Object's height contour data file (only with WAsP). There are two ways to use the data; by linking the Line Object to a Site Data Object (default) or by attaching the saved file to a Site Data Object. The latter option allows you to use the data without having a Line Object in your current project.

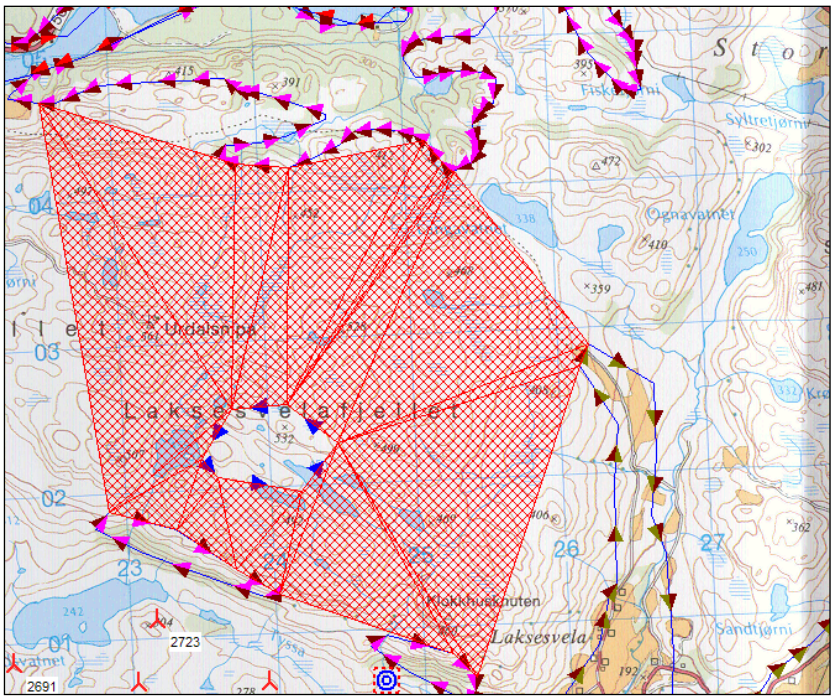
The other calculation modules (SHADOW, VISUAL, and DECIBEL) can only use DHM (the TIN) created within a certain radius around the position of the Height Contour Object. In order to be able to use the DHM you have to mark this option on the Tab Sheet **Position** under the Line Object, and indicate that the Z-coordinates of the relevant objects (WTGs, Shadow Recipients, etc.) are taken automatically from the DHM. This must also be marked on the "Position" tab sheet for the relevant objects.

2.8.7 Trimming data in Line Object

There are a number of tools available for trimming (see EMD editor)

2.8.8 Roughness consistency check

The Line Object can be used to check the consistency of roughness lines. Inconsistency is indicated as red dots or red shaded areas (see example below).



In the figure shown above, the inconsistency due to an incorrect roughness value assigned to the roughness line digitized in the middle of the area is clearly indicated (red shaded area) by the roughness consistency check. In such an example, you should return to Edit Mode and check the values of the lines (left and right in the case of roughness) to see where the issue is.

2.9 BASIS - Area and WTG Area Object

2.9.1 Introduction to Area Objects

The Area Object in windPRO provides the user with a tool for importing or digitizing areas as closed polygons, each having similar characteristics. Elements such as forests, urban areas, water, or other landscape features can be described using the Area Object. They typically have uniform characteristics and so can be treated similarly in e.g. a roughness classification or other landscape evaluation.

The Area Object has the advantage of allowing the user to quickly establish areas directly on-screen simply by using the mouse or importing data from e.g. GIS systems or maps in vector formats.

Note: Digitized areas can be used for other purposes also, and it is important to consider the intended purpose prior to digitizing.

Advanced digitizing options with auto-point settings are invoked by pressing the <Shift> key. Pressing the <Alt> key launches an eraser tool for deleting points.

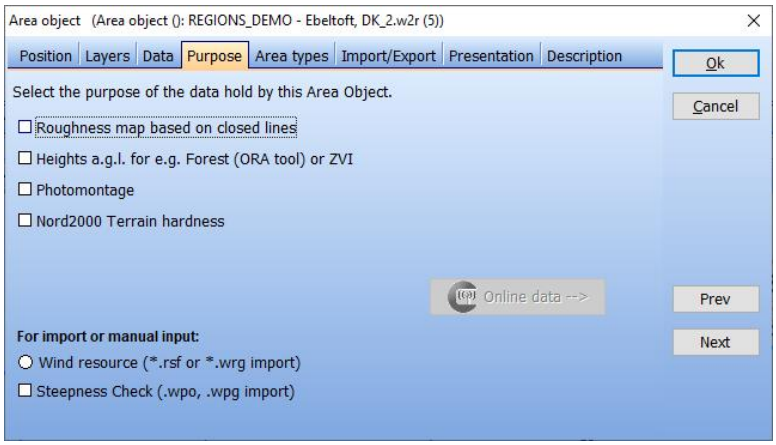
If the areas will be used for exporting a roughness line map or for a ZVI calculation, it may require the definition of landscape types. When carrying out ZVI calculations, farm land can normally be considered as one type.

In order to use the Area Object for the export of roughness lines, it's necessary to divide the farmland into different areas controlled by a roughness subset representing the farmland. For example, a division into "farm land with low roughness" and "farm land with high roughness" (many windbreaks) may be necessary.

The WTG Area Object is a special variant of the Area Object, specialized for RESOURCE and OPTIMIZE purposes and for use together with the Park Design Object. See these chapters for further details on this object.

2.9.2 Where to use the Area Object

The Area Object can be used for a number of different purposes including the shown below:



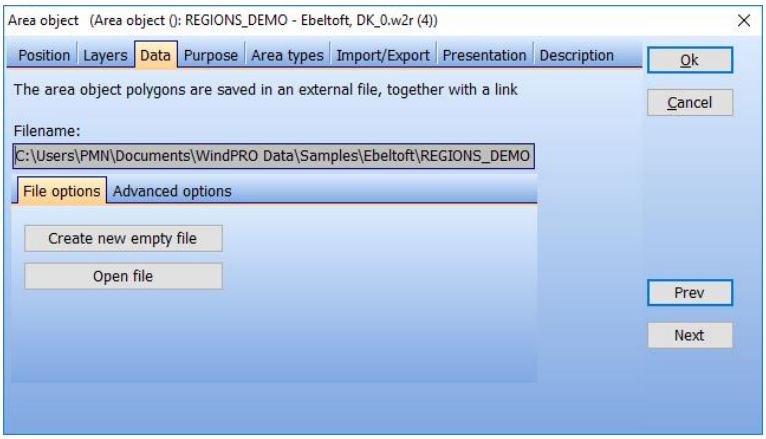
Note that the Area Object can also be used to produce roughness lines, a very useful method because it protects against crossing and inconsistent roughness lines. However, you must perform an “Export to roughness lines”, before they can be used for calculations. The exported file must be attached to a Site Data Object (via a Line Object).

With regard to crossing lines, the rule when exporting is; if areas overlap, the area with highest roughness value takes precedence over the area with the lower roughness value.

Although roughness areas can also be used directly in calculations, windPRO has a converter from roughness areas to roughness roses. It has to be noted this feature goes beyond the WAsP model, and for a full WAsP compatible calculation, the export to roughness lines should be used.

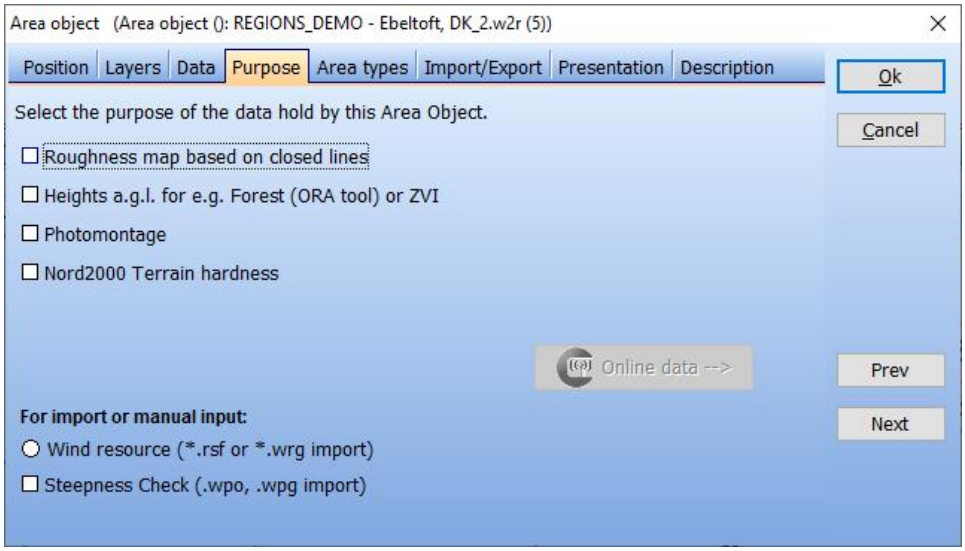
2.9.3 Establishment and presentation of the Area Object

2.9.3.1 Tab Sheet: Data



The data associated with an Area Object is saved in a file. You can create a new area file or load an existing file saved from another Area Object (a windPRO regions .wpr file). To import data from other sources, see Tab Sheet **Import/export**.

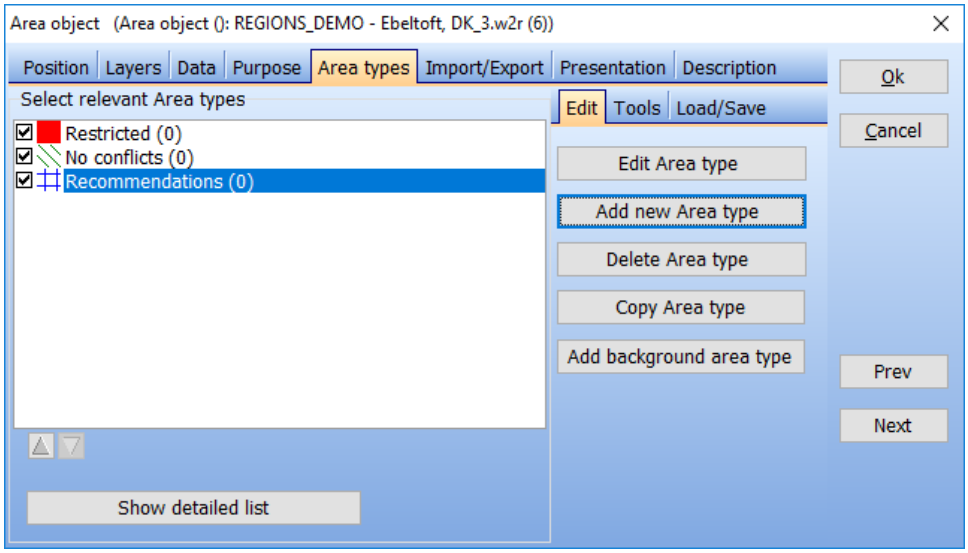
2.9.3.2 Tab Sheet: Purpose



The Area Object can have multiple purposes. More than one purpose can be checked at the same time. Note that the purpose **Steepness Check** is described in more detailed in Section 2.9.6

2.9.3.3 Tab Sheet: Area types - definition of areas

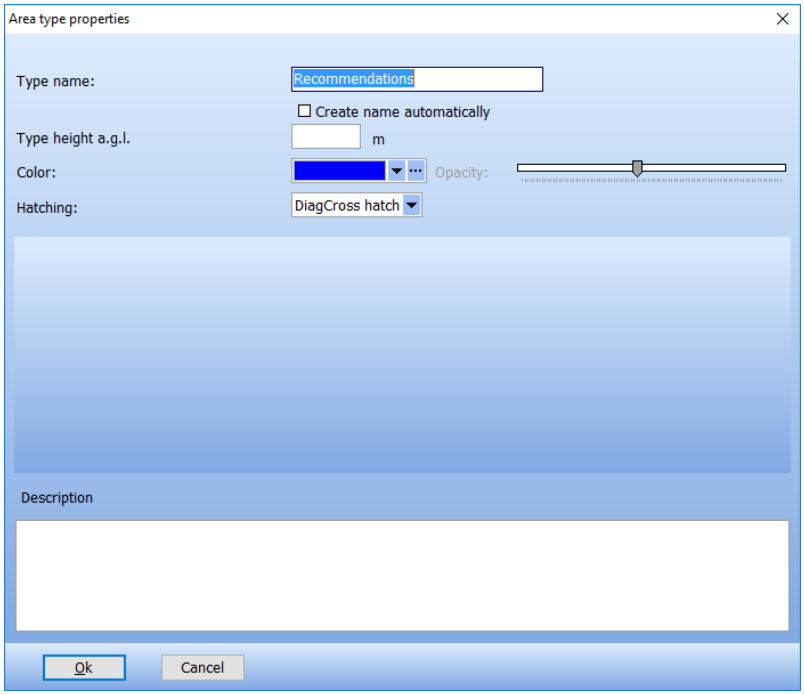
To define area types, click at an Area Object and then select either **Edit Area type** or **Add new area type**.



Definitions can be imported from a previously-defined Area Object, or from an .lty file which can be saved from the **Area type** dialog box. Some area definitions are available in the folder \windPRO Data\Standards\.

Some area types shown above are mainly for roughness classification purposes, but they are also useable for ZVI purposes.

New area types can be added by clicking on the **Add new type** option. Previously defined area types can be edited by double-clicking on an area layer name and the dialog box shown window below will appear:

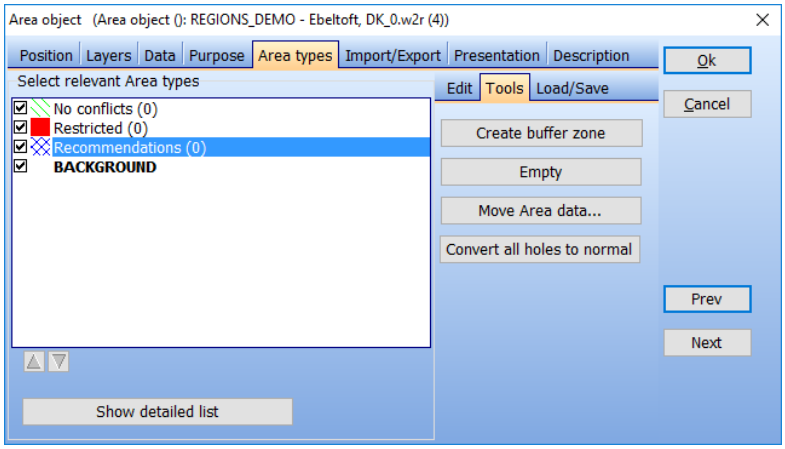


When you have finished defining or editing area layers, click **OK** and you are returned to the **Area types** window.

In this dialog box, you can check the area types you want to use for your current task. These are the ones that will appear in the drop-down selection menu when digitizing new areas, and will be visible on the map.

Edit background area type is required for roughness purposes and is optional for a ZVI calculation. The background area is the default value that digitized areas will replace where they have been created.

There are various tools available for utilizing the area types.



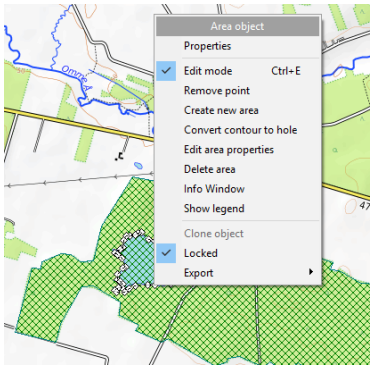
The tool **Create buffer zone** allows you to create new area types based upon already defined areas, where a new area is created in a zone defined by the user.

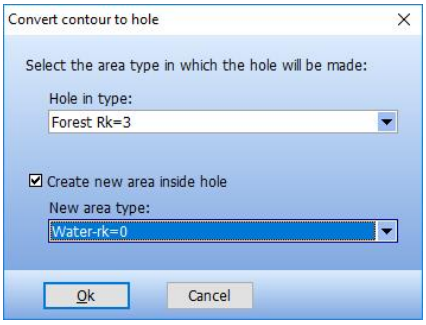
Clicking on **Empty** simply deletes the areas of a specific type

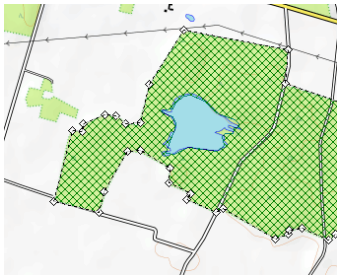
The **Move Area data…** moves area data from one type to another. This is very useful when importing data in multiple steps.

If your imported data has holes in it, all these holes can be automatically filled by clicking **Convert all holes to normal**. The holes will then take the value of the surrounding area.

Handling holes in areas.
Apart from the **Convert all holes to normal** button described above, individual holes can be managed on the map. This is the case if you have an area inside an area, like a lake in a forest. An area can be converted to a hole in the forest area, by right-clicking the lake area and selecting **Convert contour to hole**. Now the forest will wrap around the lake. The hole will have no value. If you want the hole to have another value (e.g. water roughness), then tick the **Create new area inside hole** and select a value. Then a new polygon will be created inside the new hole with the right value.



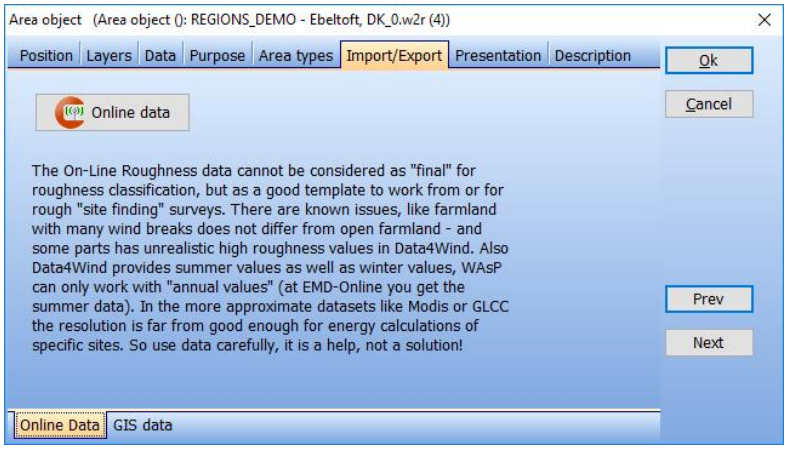




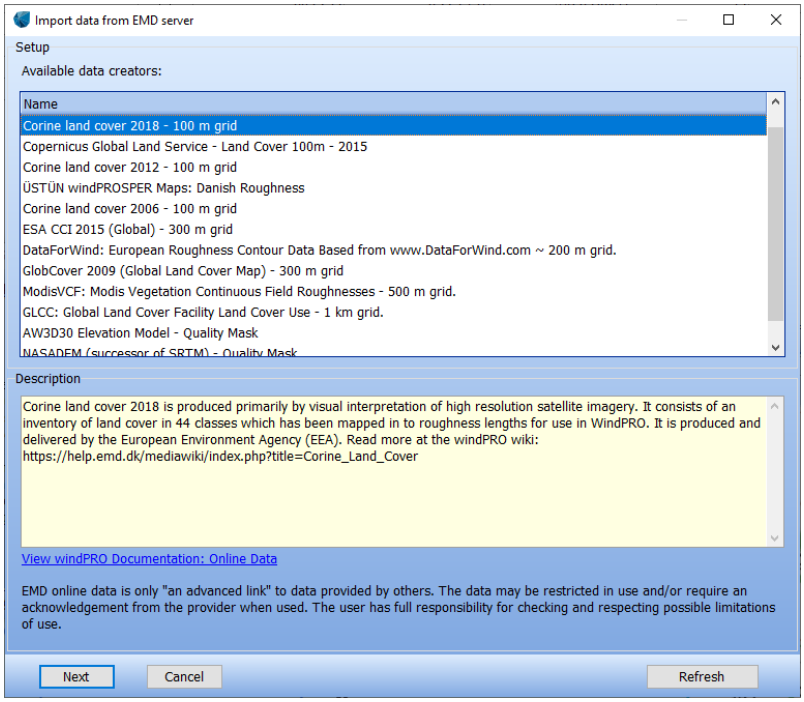
To convert the hole to a non-hole, simply right click on the area and select **Convert hole to normal**.

2.9.3.4 Tab Sheet: Import/Export – with online data

The Online data is fully automated, while import from other sources requires more settings.



*With the area object set to "roughness data" as purpose; you can get access to online data from the **Import/Export** tab.*



Example of roughness data sources at a European site.

The types of roughness data files and their roughness description is subject to availability, depending on where in the world the site is located. **Note:** these data will not be sufficient for a detailed energy calculation for a specific project, but are to be considered as an initial classification of roughness around a site. For Example, the Modis data only holds information on vegetation, not urban regions, so there will be some manual work required to edit and improve the accuracy of these data before they can be used for an energy calculation. For more information about online data visit: help.emd.dk/

2.9.3.4.1 Import from other sources

You can import previously digitized data (polygons) from other sources (.dxf and .shp files), or for a Wind Resource map, .rsf or .wrg output files from WAsP calculations.

The process of importing data is as follows:

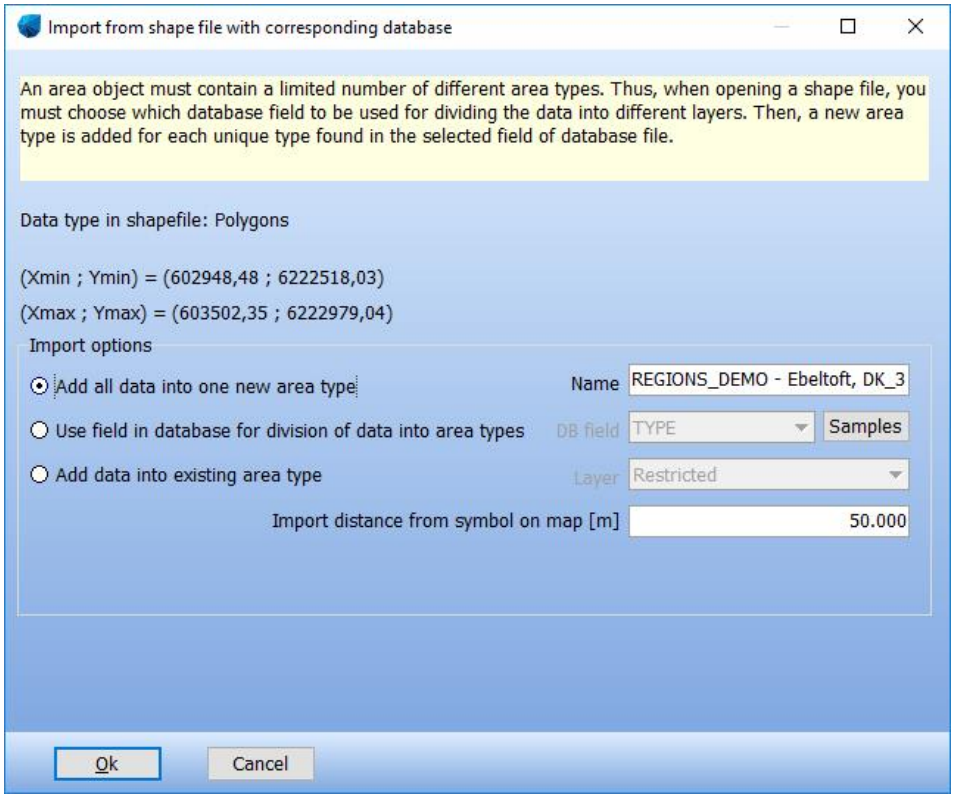
- Switch to the **GIS data** tab
- Press the **Import** button.

- Select the file to be imported
- Select the coordinate system and the datum in which the data is geo-referenced (e.g. ED 50). NOTE: This must be known. If it is a local coordinate system (or a system unknown to windPRO), it can be defined in **Project properties** prior to importing.

The procedure for importing .dxf and .shp files is slightly different as follows:

dxf-files
After reading the file (which may take a long time, start with a small file to test), the layers from the imported file appear in the list of landscape types with the layer number as the name.
Identify the imported layers and then select **Merge area layer** to place it into the defined layer that matches the type of data in the file (or redefine the layer).
Repeat the above steps until all imported layers are defined.

shp-files
After defining the coordinate system, the dialog box shown below appears:



Here you can see the corner coordinates of the shape file limits (which will indicate whether or not you've chosen the correct coordinate system – if not, cancel and chose **Import** again).

There are several options for importing .shp file data:

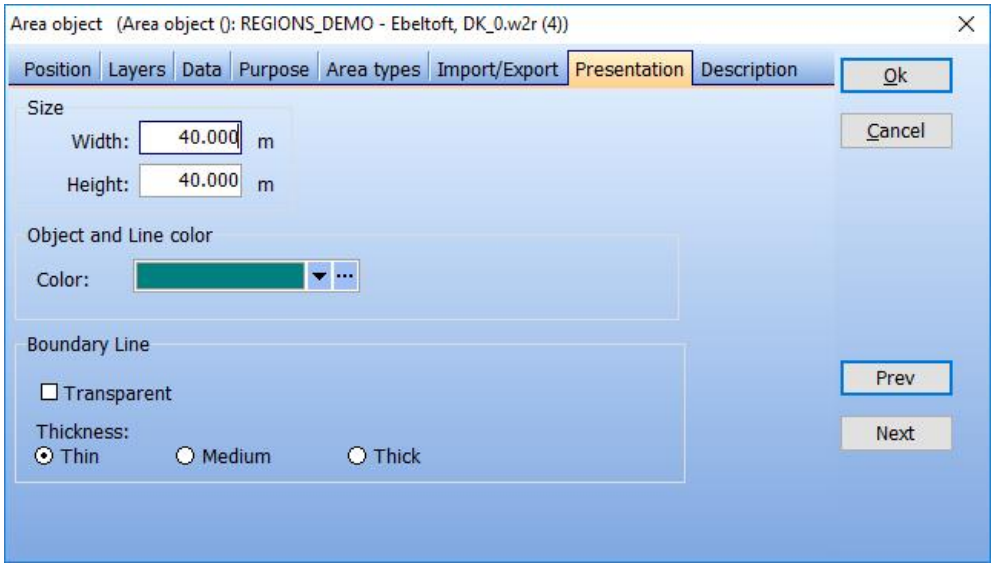
- Adding all data from all database fields into one layer
- Creating one separate area layer for each unique entry into one of the database fields or adding all data into previously-defined area layers (a more typical option).

After reading the file (which can take a long time – start with a small file to test), the layers from the imported file appear in the list of landscape types.

Caution:
When classifying roughness using areas, everything outside the digitized areas will be interpreted as the background value. The background roughness must be given a value. For example, on islands far from the mainland, it's appropriate to use the roughness value for water as the background roughness.

However, if the mainland is closer than approximately 40 km in any direction, it must be digitized and given a more typical value for the landscape. On the mainland, it's usually appropriate to choose the value for "open farmland" as background (roughness class 1-1.5) and then digitize the cities, forest, water areas, and farmland with higher roughness values. In general, everything within a 20 km radius must be digitized. At a distance of 40 km, the influence of the surface roughness normally has little measurable effect.

2.9.3.5 Tab Sheet: Presentation



In this dialog box, the visible parts of the areas are defined as width and height. The only reason to limit the visible parts would be to increase computer response when regenerating on-screen graphics.

Note that the boundary line separating each area can be made transparent. This is useful for a Steepness Check or for a Wind Resource map, where the areas cover the entire map.

2.9.4 Digitizing on-screen, editing, and viewing

Using a background map brought into windPRO as a background bitmap image (containing all relevant information, e.g. forests, cities, etc.), it's possible to digitize the sites manually, or to view the imported data on top of the map for editing as required. The same principles as described for the Line Object apply to the Area Object.

2.9.5 Save and use Area Objects in calculation modules

The data file containing the area information will be saved in the file specified in the Tab Sheet **Data** when you exit the Edit mode. Note that if working on an existing file, the file will be overwritten. To prevent this (if you have made changes you wish to undo), open the file from the Windows Explorer and make a copy before exiting the Edit mode.

2.9.5.1 Export of roughness .map files from the Area Object

From the Tab Sheet **Import/Export**, you can export the digitized polygons (if the purpose **Roughness** is checked) to a .wpo file format.

2.9.5.2 Use of the Area Object data in a ZVI calculation

In a ZVI calculation, every area defined with a height will be built "on top" of the digital height model. This means that, for every point with an assigned height inside a polygon, the assigned height from the area region will be added to the height model and, if the height of the area polygon is higher than the observer point in the ZVI calculation, the WTGs are treated as invisible from any point within this area, e.g. a forest.

Naturally, this will not always be the case. For example, WTGs can be visible from some points inside a forest or city. If this needs to be taken into account, these regions must be digitized in greater detail, e.g. each house modeled as a separate area.

In some countries, it is standard practice to create a “bare earth” ZVI where no Area Object data are used.

2.9.5.3 Export of Area Object to Google Earth

An Area object can be exported to Google Earth by right-clicking the Area object and selecting Export | Export to Google Earth kmz-file. Any buffer zones will be included in this export.

2.9.6 Trimming data in Area Object

There are a number of tools available for trimming, see EMD editor

2.9.7 Steepness calculation and presentation

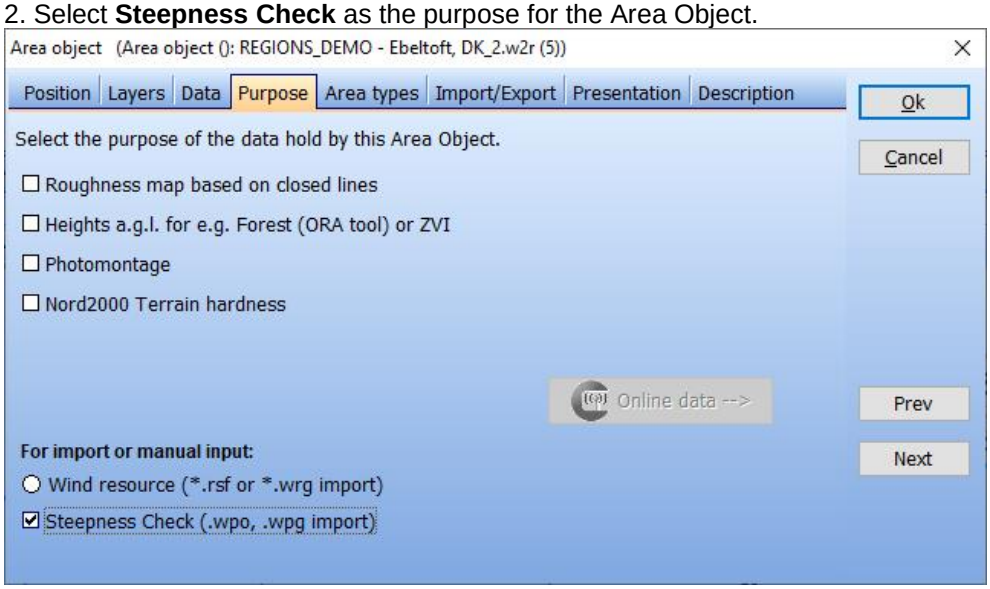
2.9.7.1 Purpose of the Steepness calculation

The Steepness Check (.wpo import) is used to generate areas (polygons) containing the “steepness” within certain intervals. These intervals may be used to exclude areas where it’s impossible construct turbines or to build roads due to the steepness of the slopes of the terrain. The input data is a *.wpo file from a windPRO Line Object, and the result is placed in an Area Object.

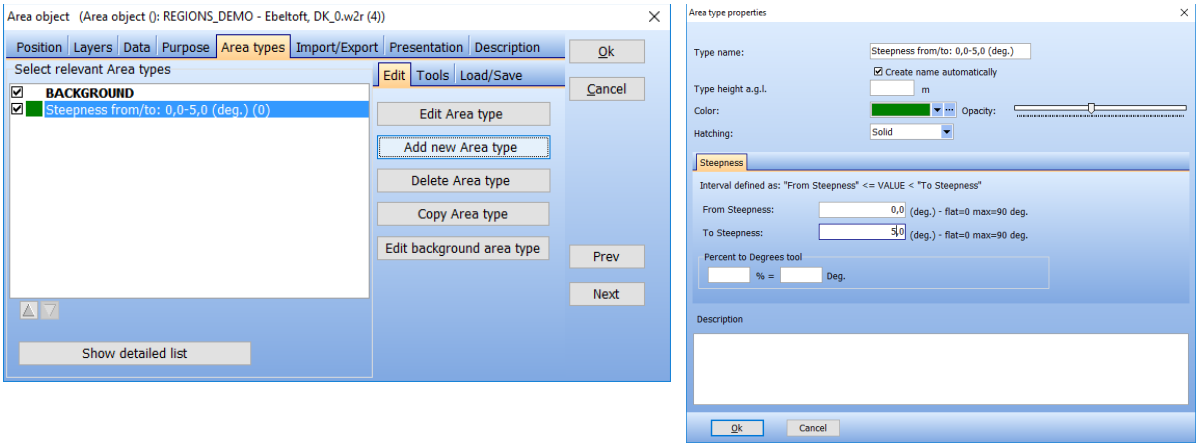
2.9.7.2 Calculation setup in the Steepness calculation

1. Insert an Area Object onto the map using the icon.

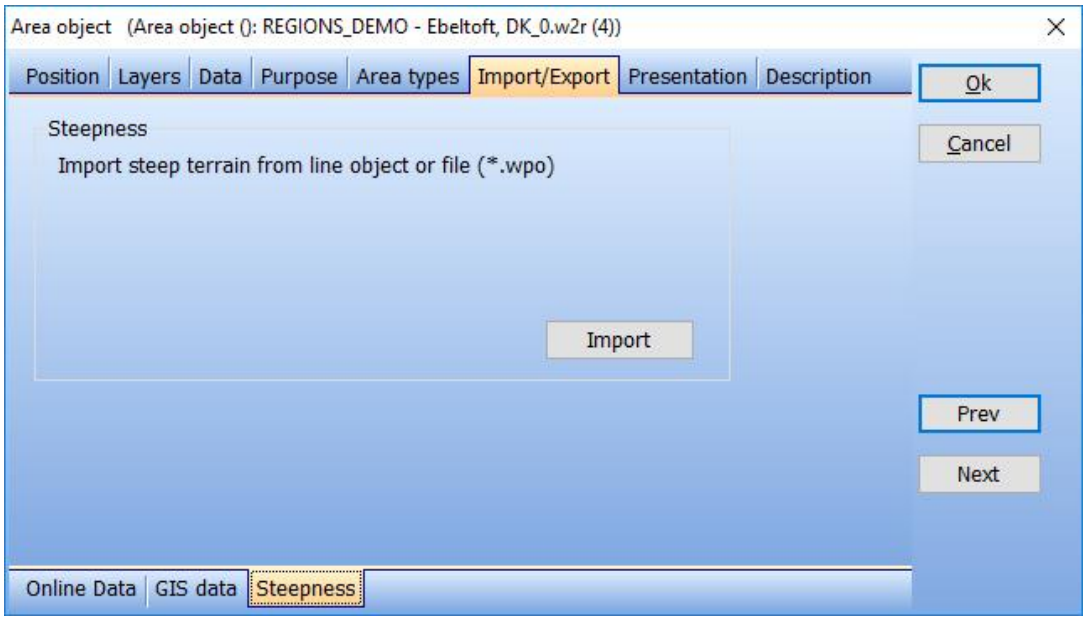
2. Select **Steepness Check** as the purpose for the Area Object.



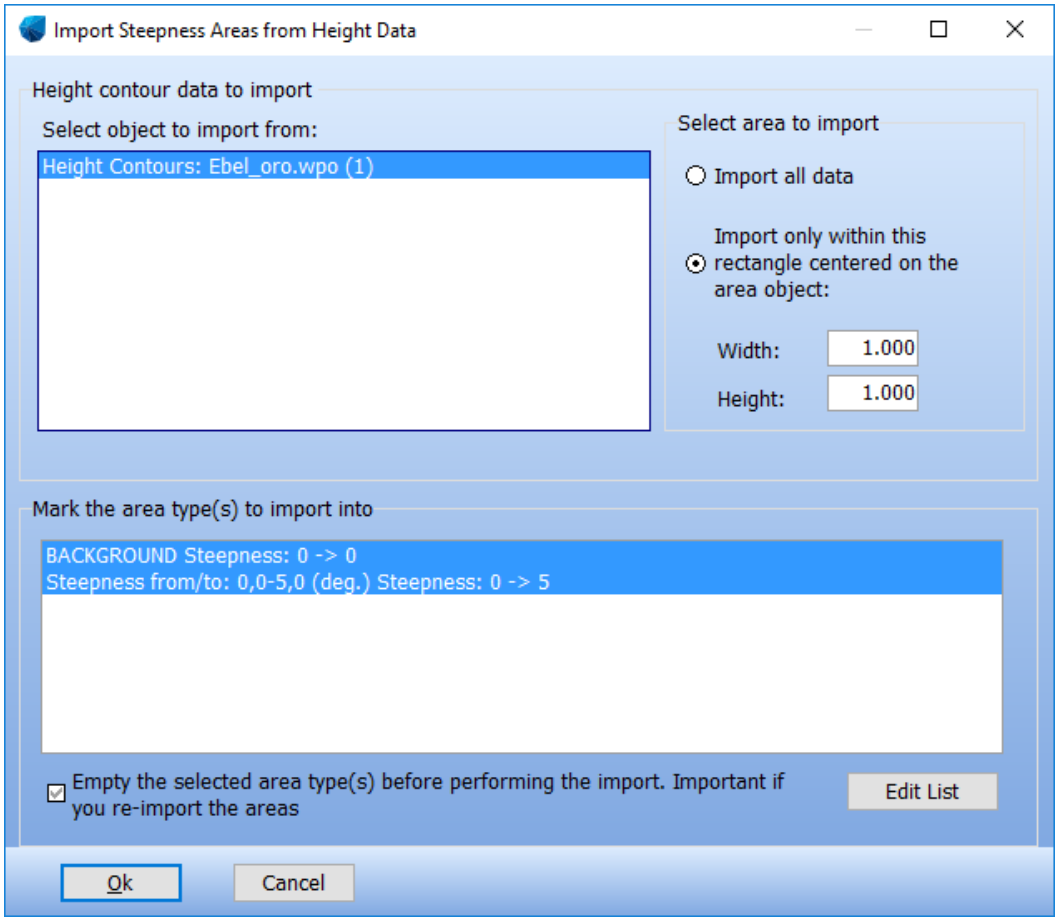
3. Create an area type for each steepness interval that should be created. Click on the **Add new area type** button on the **Area types** tab sheet.



4. Select Import from the Import/Export | Steepness tab sheet.

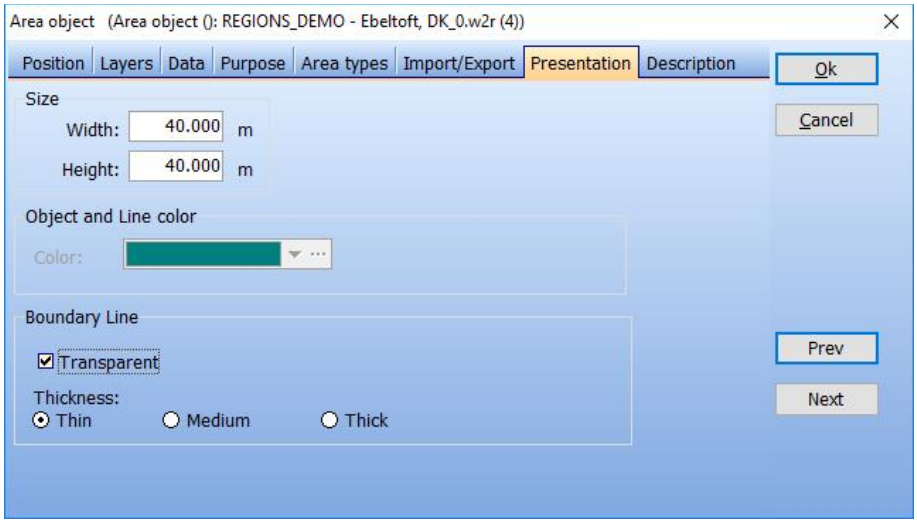


5. Now, select the *.wpo file (Line Object data file) to calculate or import the steepness data from. Mark the area types to import into (the areas that you just created). On import, windPRO reads the steepness intervals from the area types. Make sure to mark the **Empty the selected area type(s) before performing the import**, if you re-import the areas. Otherwise, duplicate areas are created.

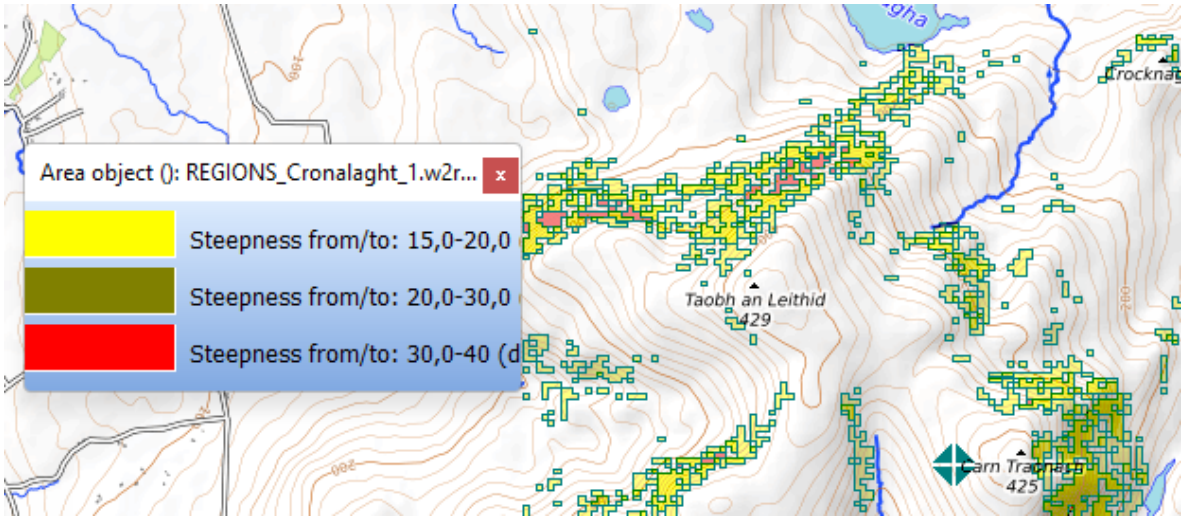


There are a range of pre-defined steepness limits in the windPRO Data | Standards folder which can be loaded by clicking on **Edit List** and then Load**.**

6. Lastly, in order to make the slopes look good on the map, select the Boundary Line to be **Transparent** on the **Presentation** tab sheet.

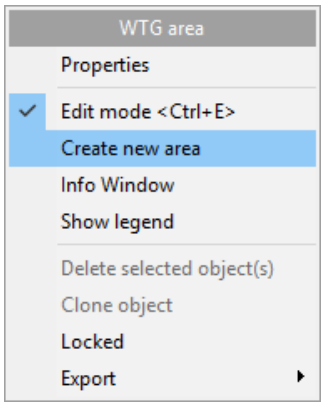


An example of results from a steepness calculation is shown in the figure below. Note that the turbines are erected in areas where the steepness (slope of the terrain) does not exceed fifteen degrees, i.e. where no areas are colored.

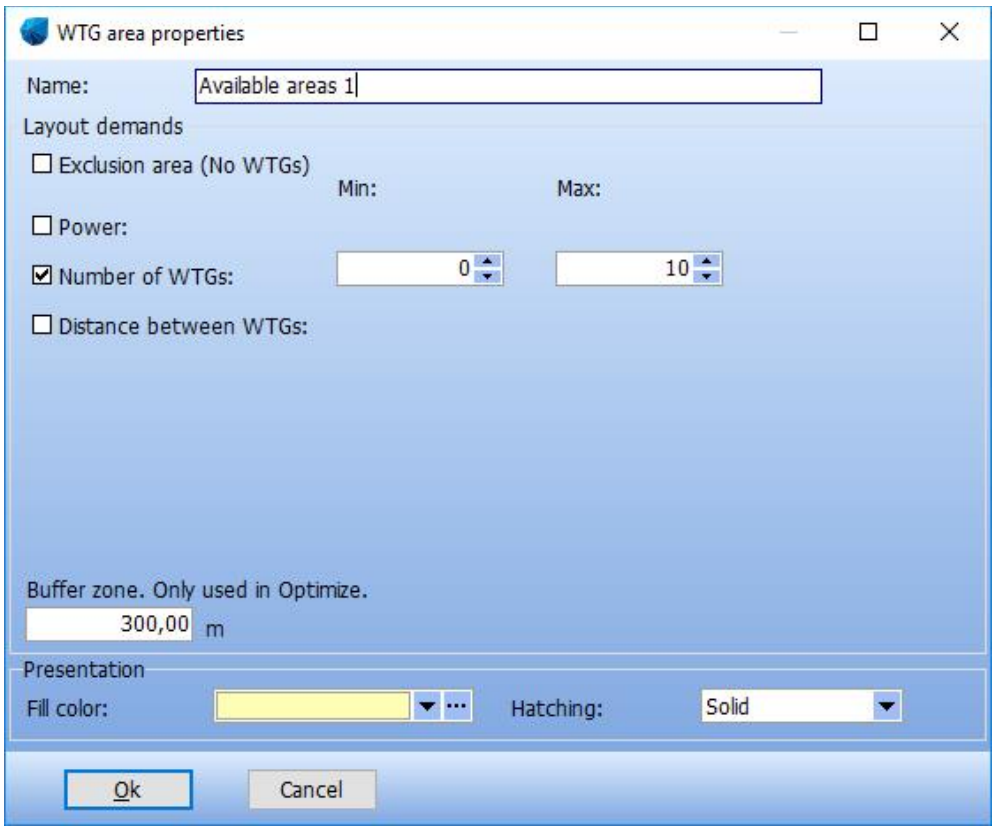


2.9.8 Specific WTG-area features

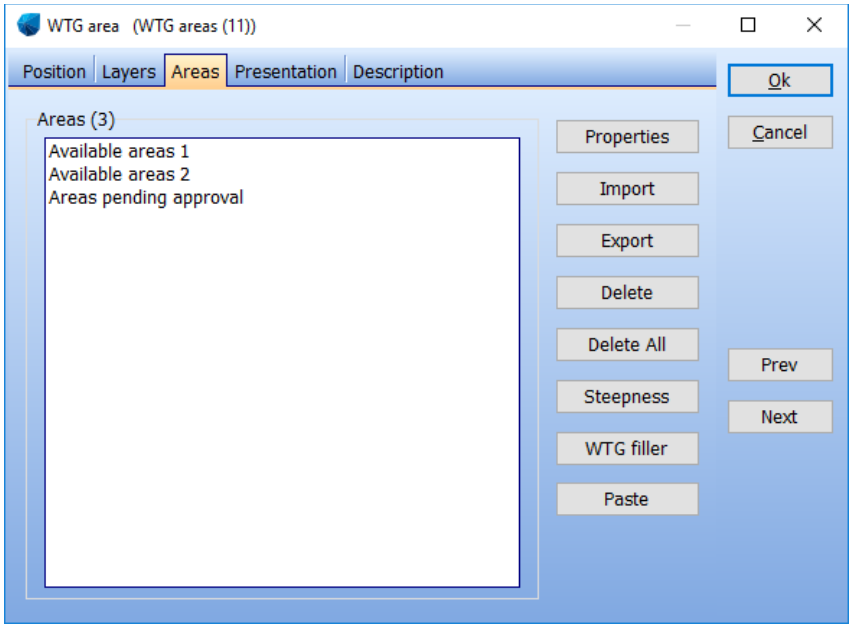
The WTG-area is as mentioned a variant of the Area object with limited features, but specifically designed for having the most needed features for designing a wind farm. The object is central to the OPTIMIZE module and is typically used as the object that defines the borders of the site, e.g. based on land owner agreements. For further information on the WTG Area Object see Chapter 8, section 8.1.2



Once a WTG area object has been added you can digitize the areas on the map by right-clicking and selected **Create Area.** Before the digitization can begin, the WTG area properties is to be defined:

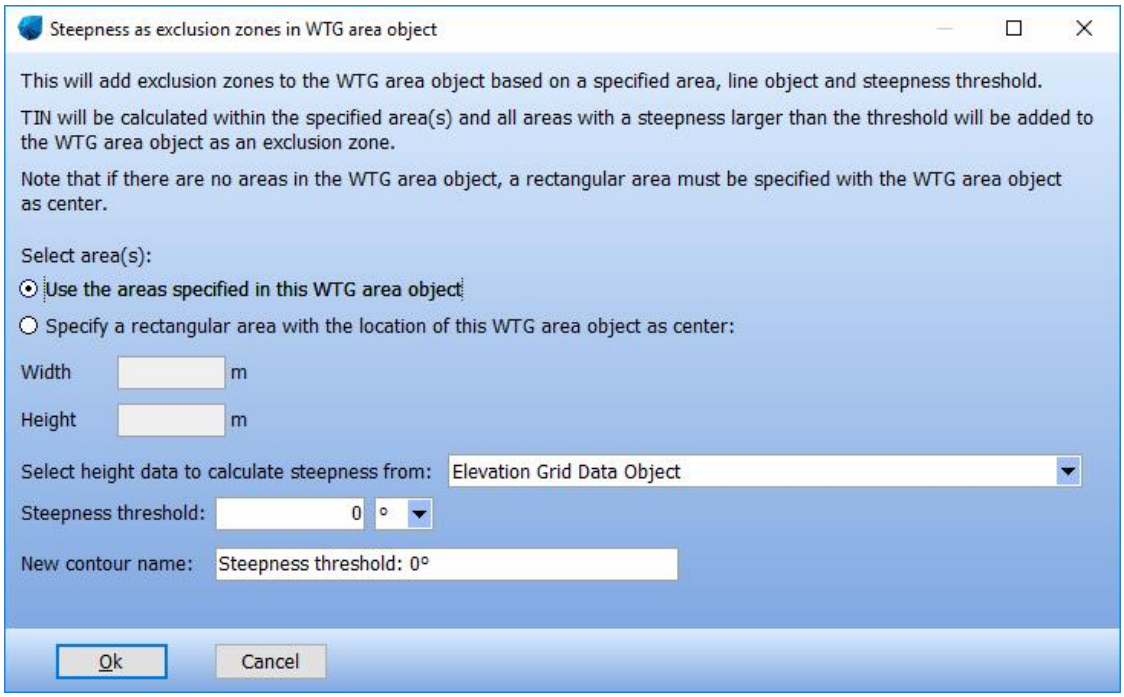


Here you give the area a name (e.g. the landowner) and specify the constraints that the optimizer must respect such as the amount of power to install, number of turbines, etc. You can add a buffer zone to the area, which cuts the specified distance into the digitized area. If no turbines are allowed in the area, simply click the **Exclusion area (no WTGs)** checkbox, to make sure no turbines are added in the area (by the Optimizer, they can still be added manually if required). If the area is an exclusion area, the buffer zone works reversely, as it is extended the specified distance outside of the digitized area.



Opening the properties of the WTG area object shows you the different digitized areas. Double-click one of these to edit their properties (as defined above).

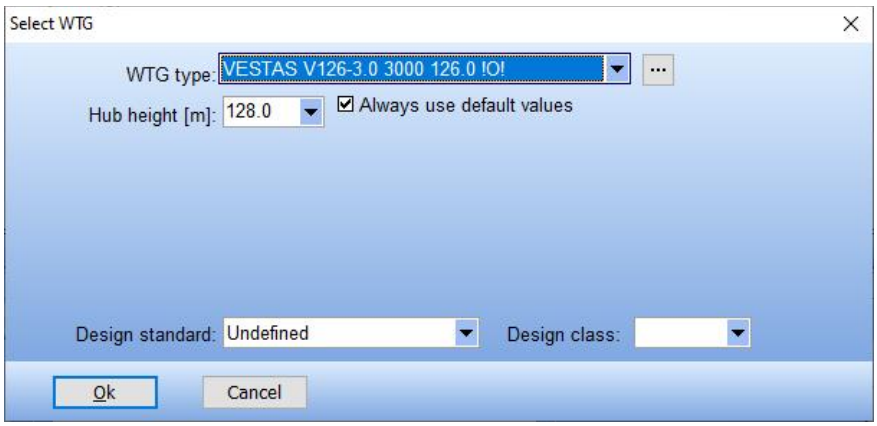
2.9.8.1 Steepness in WTG-area



Steepness can be established as exclusion zones based on a given steepness threshold. This is very efficient for avoiding placing turbines from e.g. the OPTIMIZE module in areas that are too steep.

2.9.8.2 WTG filler in WTG-area

The WTG filler can establish as many turbines as there are space for based on required distances, a fast way to evaluate the MW potential at a given site.



For further information on the WTG Area Object see Chapter 8, section 8.1.2

2.10 BASIS – Elevation grid object

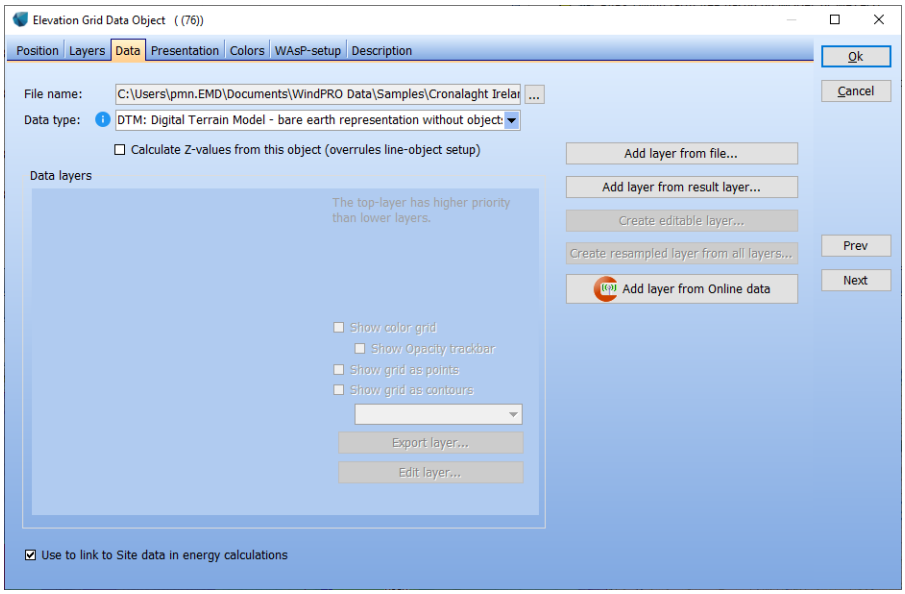
2.10.1 How to use the elevation grid object

With the Elevation Grid Object, it's possible to handle elevation data as gridded data meaning that the elevation data has a Z value for each point in regular grid spacing. This makes calculations much faster compared to contour lines and it gives options to present the elevation data in color scales to give a good overview of the elevation on a map. A special feature is the layer organization of the elevation data, where more layers mean that detailed data near the site can flexibly be combined with more coarse data in the remote region. While gridded elevation data normally not are editable, there has been established a special feature for creation of an editable layer, where grid data are converted to lines in a line object that can be edited and thereby like near measurement masts very detailed data can be established. The elevation grid data is thereby an efficient alternative to line object contour elevation data.

2.10.2 Creating an elevation grid object

Click on the Elevation Grid Data Object button.

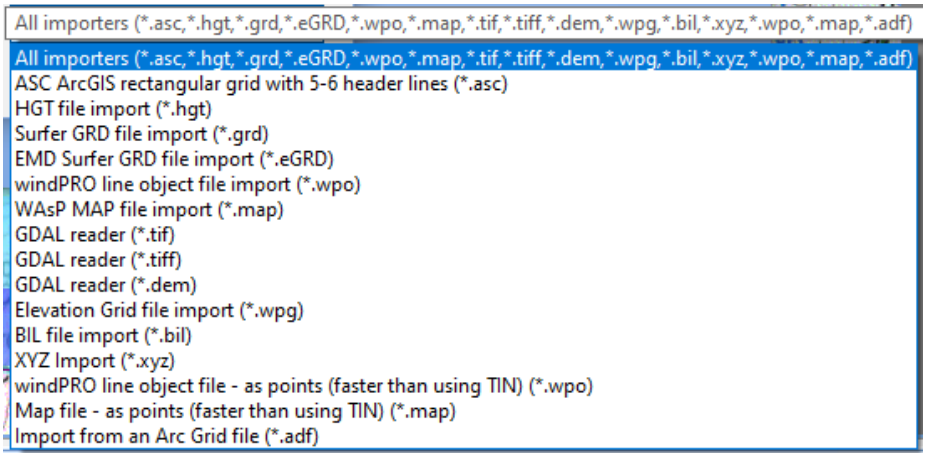
2.10.2.1 Tab Sheet: Data

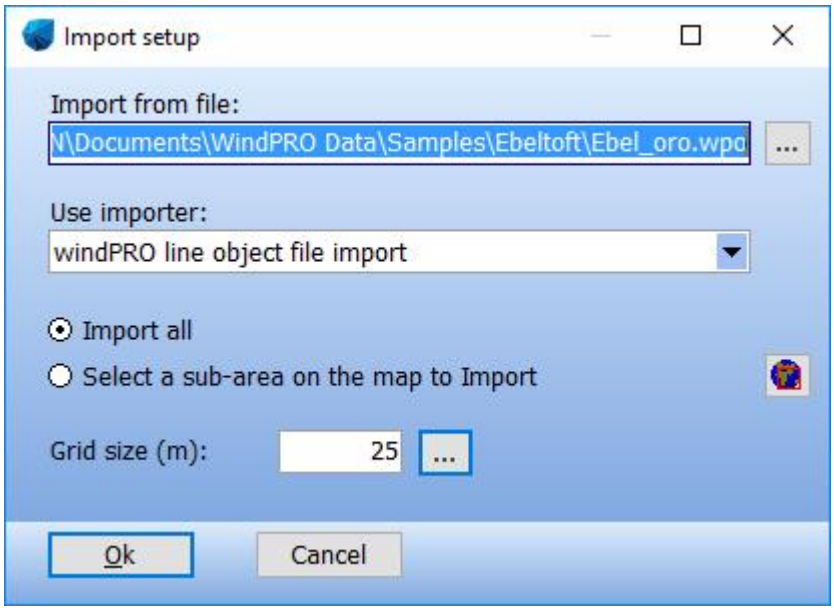


You can specify if the elevation data (Z value) for all objects in the project should be calculated from the elevation grid data object. If there are several elevation data objects in the project, like for instance a line object and an elevation grid object, you have to choose which of these two alternatives should be used to calculate the elevation (Z value) of all objects in the project. If there is only an elevation grid data in the project, no choice is needed.

On the Tab Sheet **Data**, you specified which data to load.
The simple way to get data is to use **Add layer from Online data**, where multiple data sources are gridded and easily loaded.

Click on the button **Add layer from file** to specify one of the following file types:

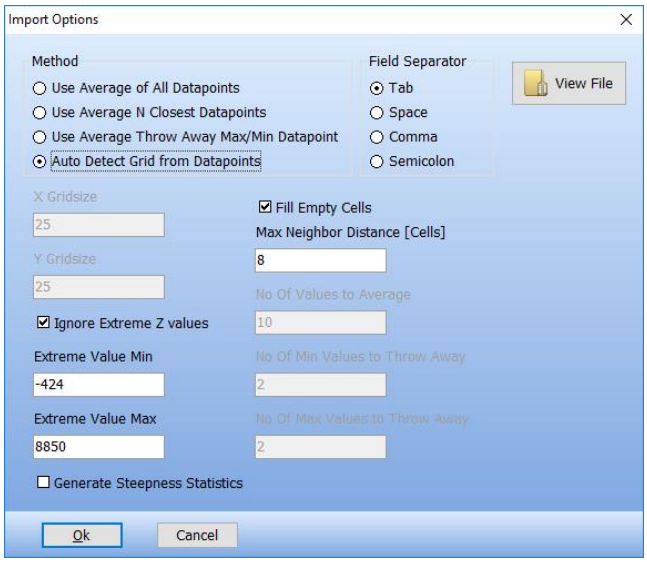




After selecting a file the next step is to choose an importer (often only one option), and then to decide if all data or a geographical sub set of data shall be imported. Finally the grid size must be decided. As opposed to the line object data, the size of an elevation grid is not a trivial decision. Too high a resolution gives too many points, too low gives poor accuracy. Remember that the import can be done

in more steps, making it detailled, for example 10m equidistance near the site, and coarser, such as 100m for the rest of the area.

Importing xyz data into an Elevation grid:
If your data are saved in a xyz format within an irregular grid a special xyz importer will be used. The xyz importer can be used to convert irregular grid to regular grid, and to thin out very detailed gridded data. For instance, the data in Lidar surveys might have many point values every m^2, which means the data amount is too detailed for typical wind energy calculations.

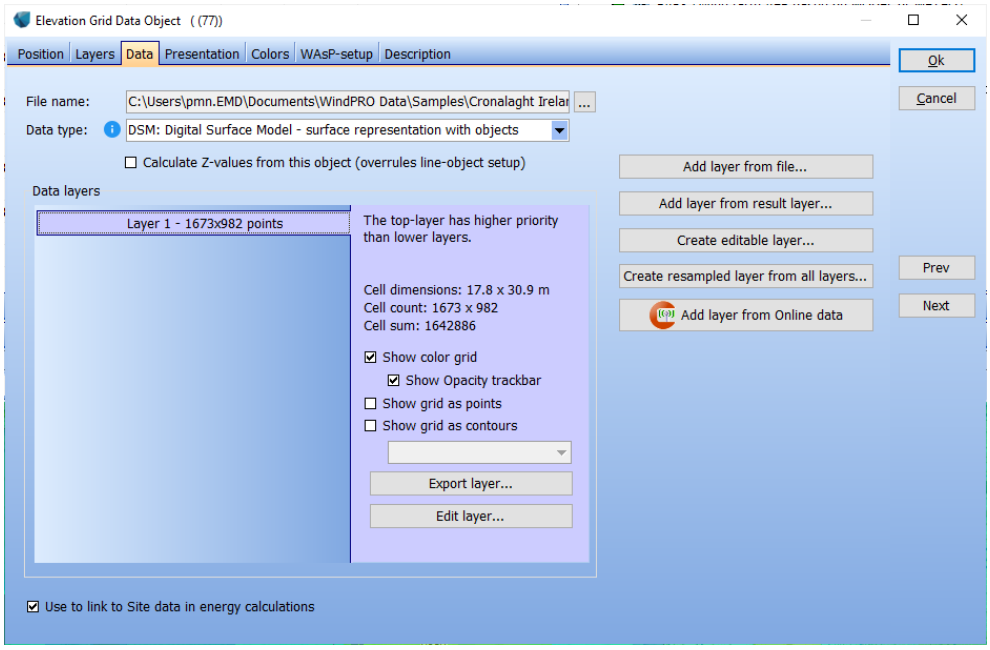


The xyz importer has four import methods:

- Use Average of All Data points:
  - Calculates the average value of all data points in a given grid cell and assigns that to the grid cell.
- Use Average N Closest Data points:
  - This is the typically used option, which calculates the average value of the N data points nearest to the center of a grid cell, while only considering data points that contribute to the given grid cell, and assigns that to the grid cell.
- Use Average Throw Away Max/Min Data point:
  - In case the data quality is poor, use this option. It calculates the average value of all data points that contribute to a given grid cell, but ignores the M values with the highest values and the N data points with the lowest values. The average of non-ignored values is assigned to the grid cell.

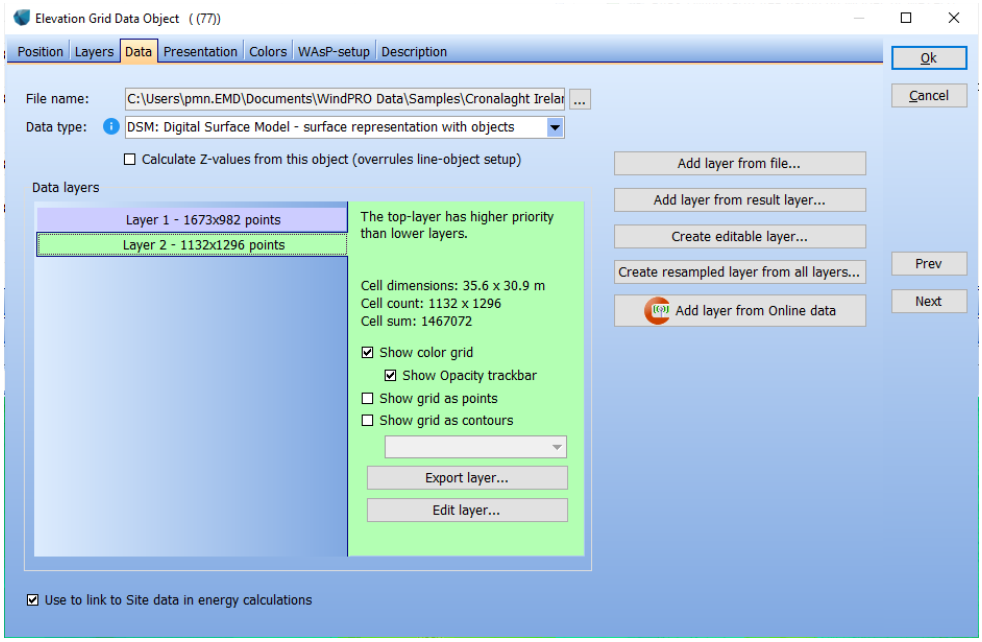
- Auto Detect Grid from Data points
    - This is the preferred option for highest possible resolution: The method tries to construct a grid that fits perfectly to the data such that exactly one data point goes into each grid cell. If the data set constitutes a perfect grid of a reasonable small size, then this method is the preferred one as it will reconstruct the original grid.

The Fill empty cells option is also important. Normally, you do not want holes in your data and therefore you want to fill these with averaged values from neighboring cells. However, be aware that the data might be at the top of a curved ridge, and you risk filling within the curve. So, there can be compromises. The “filled curve” can be erased later with the **Edit layer** option, so the lower layer data is taken within the curve.

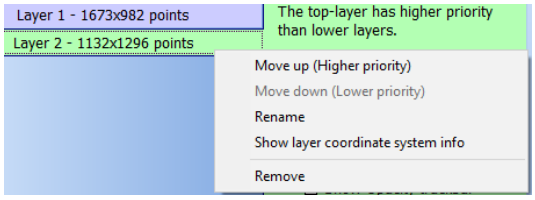


After import, some information is shown and the first layer is established.

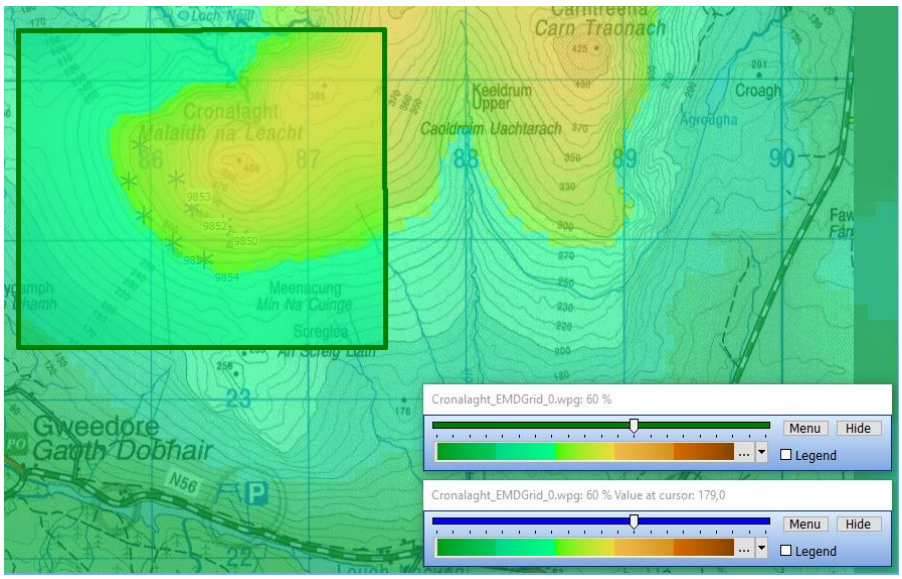
It is possible to add an additional layer in the site with a higher grid resolution:



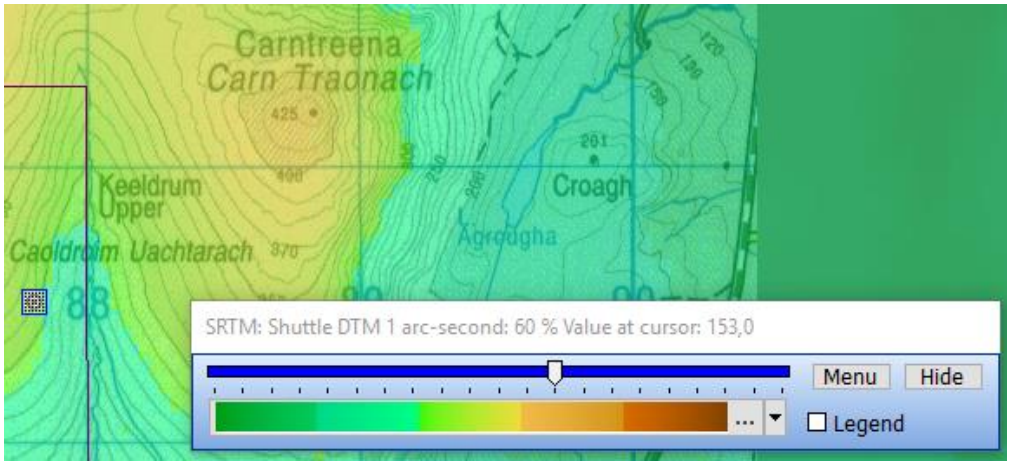
By right-clicking on the layer, the layer can be moved to the top layer. This mean that data from this layer are taken first in any calculation.



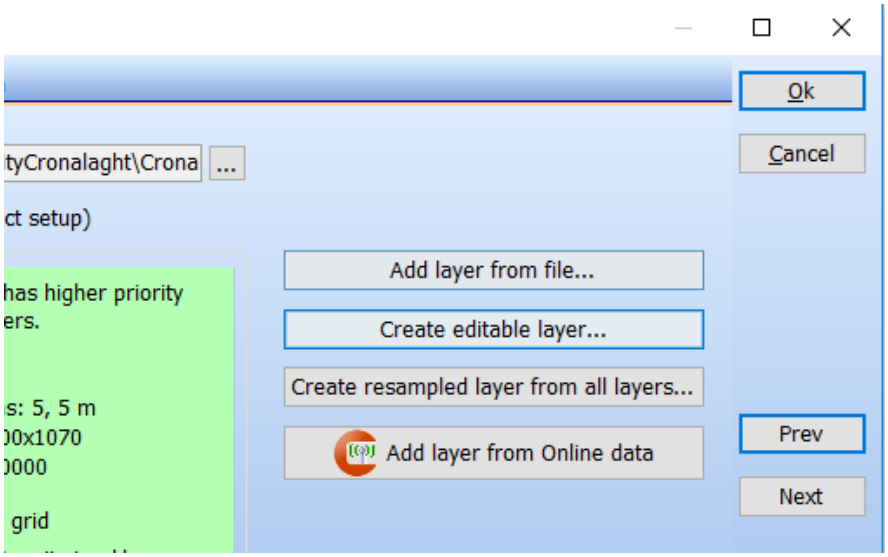
Contour lines calculated from the grid data can be shown in any resolution. The grid points can be shown and along with high resolution painting of the grid, correcting the problems given by the Earth's curvature.



The presentation by default looks like this.



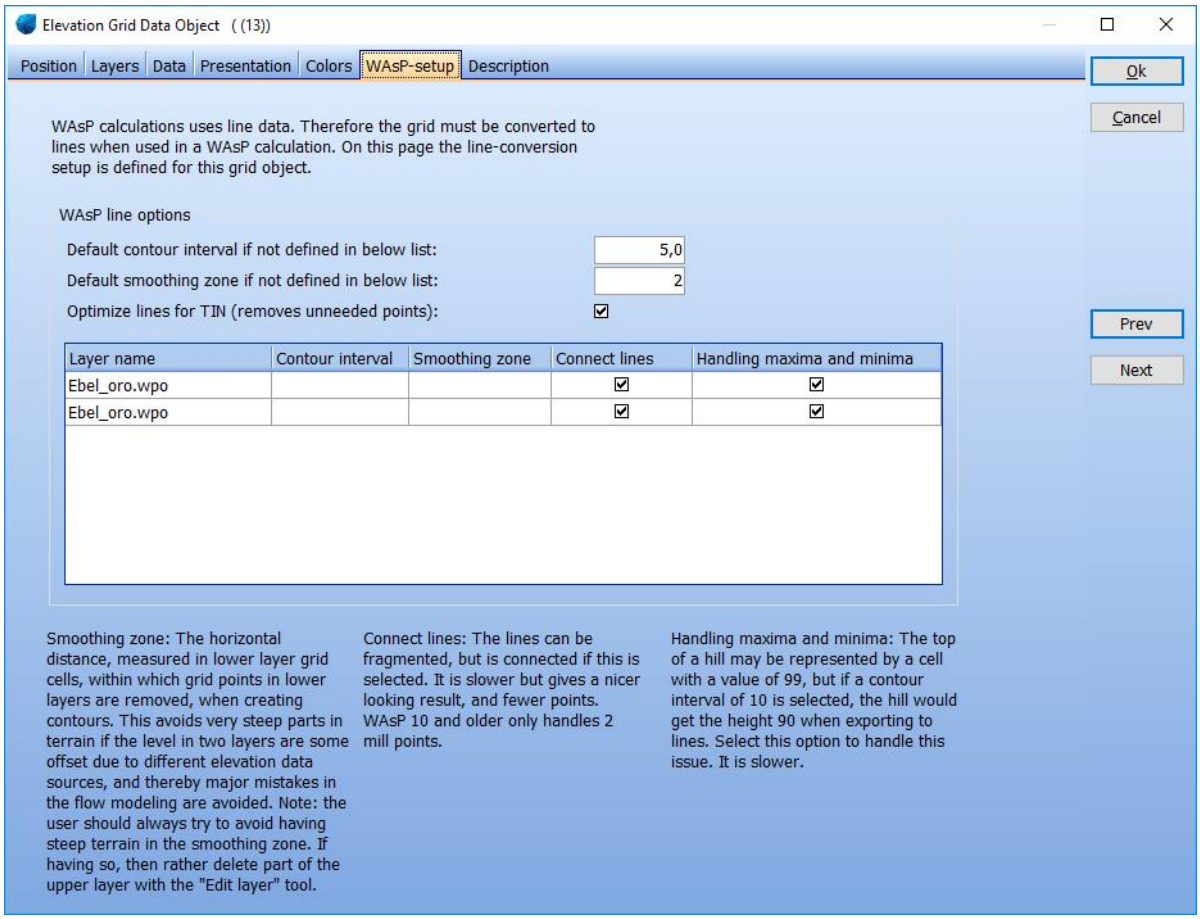
Chosing another color scale and zooming in, shows how the different layers has different resolutions. With the opacity track bar the visibility can be changed. Legends can be added and color scale settings changed. The “presentation” and colors are similar to Line objects and Result layers.



Sometimes it can be useful to edit gridded data. This can be done by creating an editable layer, making it possible to “hand digitize” special areas of interest very accurately, e.g. the region around a measurement mast, camera object or WTG locations.

When creating an editable layer, the gridded data are exported as contour lines to a Line object for the specified area. The data is auto imported to a Line object. This can then be edited by the tools described in Line object. When editing is finalized, the data are automatically converted to grid data and replaced in the Elevation Grid object.

2.10.2.2 Tab Sheet: WAsP setup



The WAsP setup is special, as it allows for different contouring intervals for different layers. In mountainous terrain, it can be an advantage to reduce the resolution in more remote regions to avoid too many points/lines, which can violate the WAsP capability.

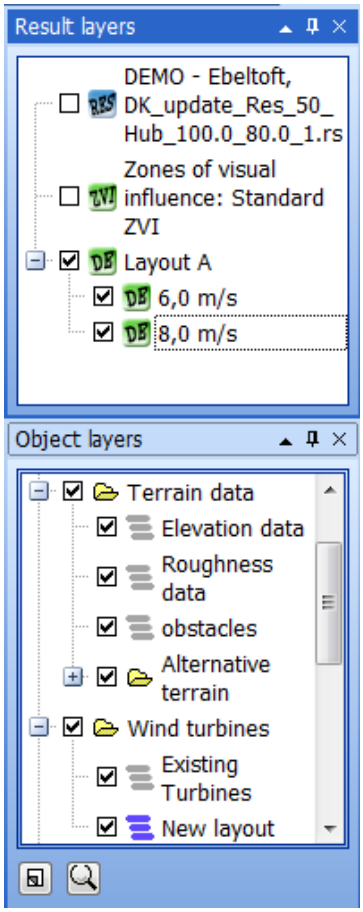
The smoothing zone is established to avoid steep regions. In cases where two different sources with slightly different elevation levels are used for the detailed and remote region, conversion to lines for WAsP calculation would create some very steep slopes in the transition zone. Therefore, a smoothing zone can be defined based on a number of grid cells.

2.11 BASIS - Layer structure - results and objects

2.11.1 Introduction to layer structure – docking

Using a layer structure similar to that used in many programs such as Google Earth™, AutoCAD™ or Photoshop™, you can organize the results (geographical results) and objects in windPRO. There are basically two layer structures: The result layers and the object layers.

The result layer structure is placed in a layer structure above the object layer structure, see screen below.



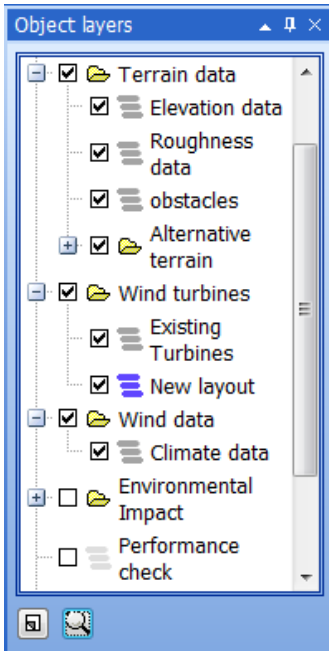
The result layer structure can be organized in sub layers, which is different from the object layer structure. From several calculation modules, like DECIBEL, SHADOW, ZVI, and RESOURCE, result layers can automatically be created. But result layers can also be established by right clicking in the result layer window, where files can be manually added, like .rsf files (wind resource files from WAsP or CFD tools).

The result layers have the same options for color scales and legends as for report printing and viewing elevation grid data.

The icon for the Result layer windows is , and the icon for the Object layers window is

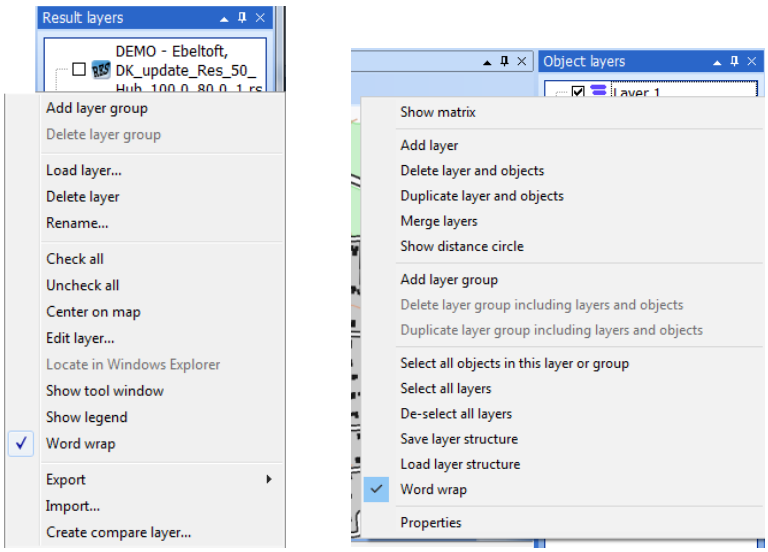
2.11.2 Create new layers and basis management

In the Object Layer window you can create a new object layer by clicking on the small **Add Layer** icon at the bottom of the page. The checkboxes next to the layers show which has their objects visible on map and in object list. The blue lines indicate the current active layer. Any new objects created will be assigned to this layer until you click another layer and make this active. Layer groups can also be created to organize the layers.



Result layers are created from calculations (auto-created when this option is checked), but can also be created by right click in the result layer area. The same goes for object layers.

An object layer can be cloned in the right-click menu item called "**Clone layer and objects**". The same goes for layer groups



The right click menu in result layer area (left) and in the object layer area (right).

2.11.3 Result layers

Result layers are typically established from a calculation.

Parameter	Hub height	WTG	Use lines	Edit line setup	Use raster	Edit raster setup	Show in result layer
Specific energy (kWh/m2	100,0		☐	Edit	☑	Edit	☑

An example from wind resource map calculation. Check the **Show in result layer** and the layer will be created when the calculation ends.

2.11.3.1 Load or import into result layers

There is a difference between loading and importing into result layers from external files.

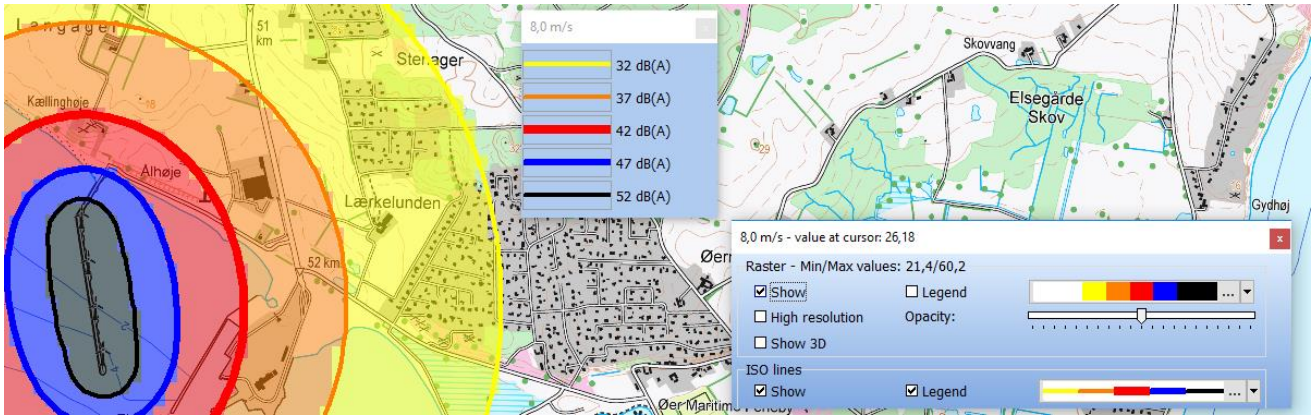
Load can add wind resource files (.rsf or .wrg files) while these has a special status with a known structure that has more different types of data that can be presented.

All importers (*.asc,*.hgt,*.grd,*.wpo,*.map,*.tif,*.tiff,*.dem,*.wpg,*.bil,*.xyz,*.wpo,*.map,*.adf)
ASC ArcGIS rectangular grid with 5-6 header lines (*.asc)
HGT file import (*.hgt)
Surfer GRD file import (*.grd)
windPRO line object file import (*.wpo)
WAsP MAP file import (*.map)
GDAL reader (*.tif)
GDAL reader (*.tiff)
GDAL reader (*.dem)
Elevation Grid file import (*.wpg)
BIL file import (*.bil)
XYZ Import (*.xyz)
windPRO line object file - as points (faster than using TIN) (*.wpo)
Map file - as points (faster than using TIN) (*.map)
Import from an Arc Grid file (*.adf)

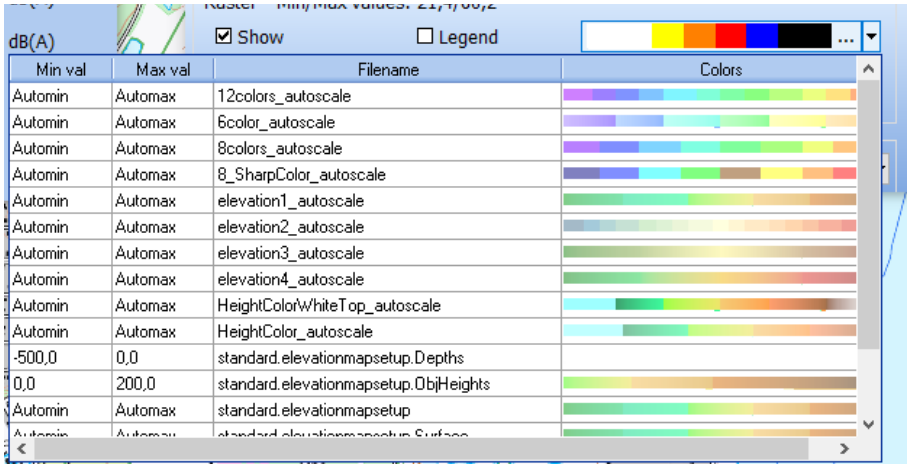
Import handles different file types, see list above, which will be expanded later.
Note: If elevation data are to be used for calculation purposes, these shall be loaded in the Elevation Grid object, not as result layers. Result layers are only for presentation.

2.11.3.2 Result layers presentation setup

A very important feature for the result layers is the presentation setup.
Double click the specific result layer in the result layer list, and the Tool Window appears.



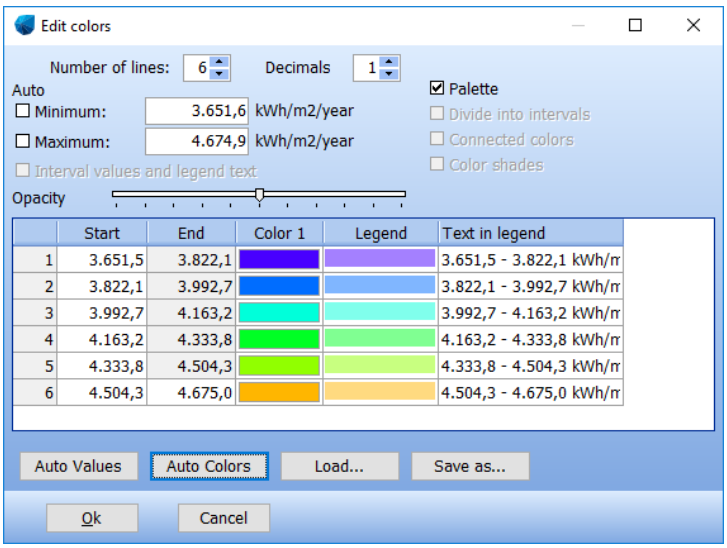
The Tool Window gives access to line and raster settings. It's easy to choose another color scale using the drop down menu, or fully define a color setup by clicking "..." next to this. Note the opacity adjuster, making it possible to set the transparency of the result layer. It is possible to show the result layer on a 3D map by selecting Show 3D (see 3D Map view). When moving the mouse across the map, the value at cursor position is shown in the top bar of the Tool Window.



The drop-down menu on the color scale shows the defined color scales, as well the ones included in windPRO as user-defined. The color scales are shown with the present data loaded. Therefore only the ones with auto min/max will be shown with a full color scale while other based on fixed values might not be within the relevant range and therefore just display as white. These scales can still be chosen and the values can be edited. The edit mode is entered pressing the "**...**" button.

2.11.3.3 Color scheme editor

A set of color scales for rasters and lines are saved in files located in \windPRO Data\Standards\, with extensions:
*.linecolorsetup
*.rastercolorsetup



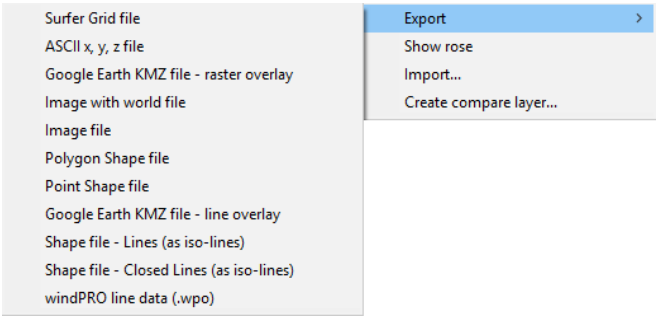
The color scheme editor. When auto min, max and interval are checked, a general purpose color setup is created, where min and max are auto adjusted to the content in the loaded data. With Save As this can be saved and will appear for later use. Whatever color settings are made can be used in current view without saving.

When Auto is unchecked, values can be entered in the min/max fields, and clicking on **Auto values** will create the intervals based on the **Number of lines**. **Auto color** generates a color scheme, by clicking in the color fields these can be edited manually.

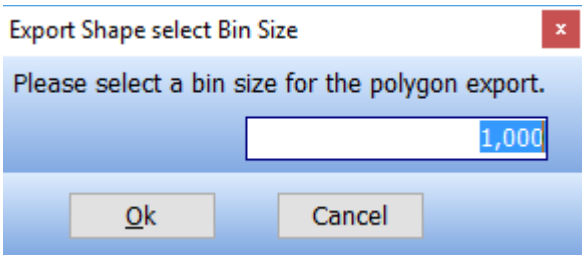
The four options seen in the top right corner, such as Palette, Color shades, etc., provide some flexibility in designing color schemes.

2.11.3.4 Export of result layers

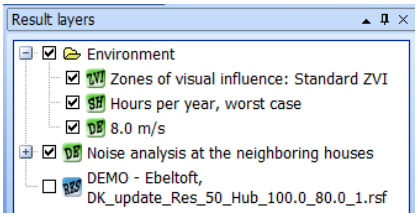
The result layers can be exported to numerous formats. Right click on the result layer and select export. Depending if it is line or raster data (or both) shown, different types of exports are available.



If exporting to a Shape Polygon file you will need to select a bin size if the values are not integer values.



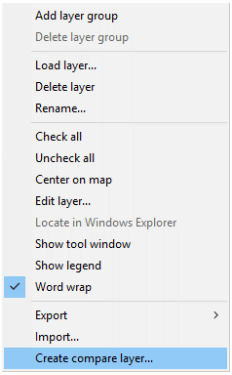
2.11.3.5 Organizing result layers in folders



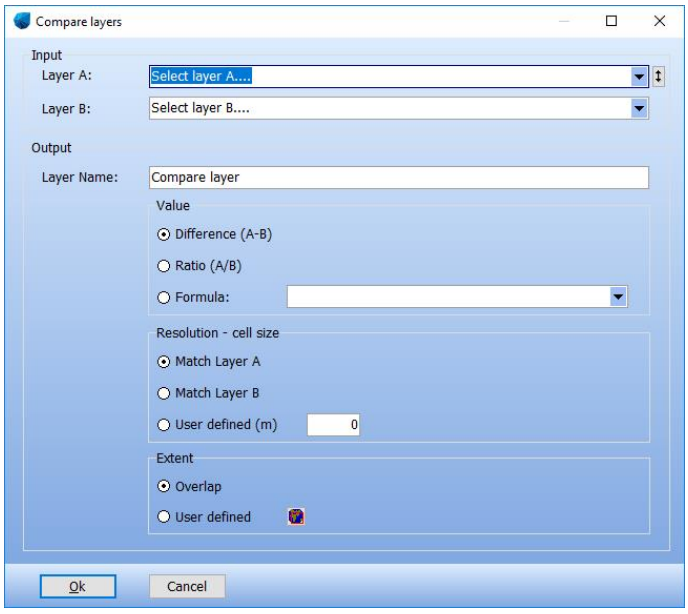
By right clicking and selecting **Add layer group**, a folder symbol appears, and result layers can be organized by drag and drop.

2.11.3.6 Comparing result layers

You may want to compare two result layer to see the difference between them. Right clicking in the Result layers window, it is possible to select **Create compare layer:**



This opens the “Compare layers window”:



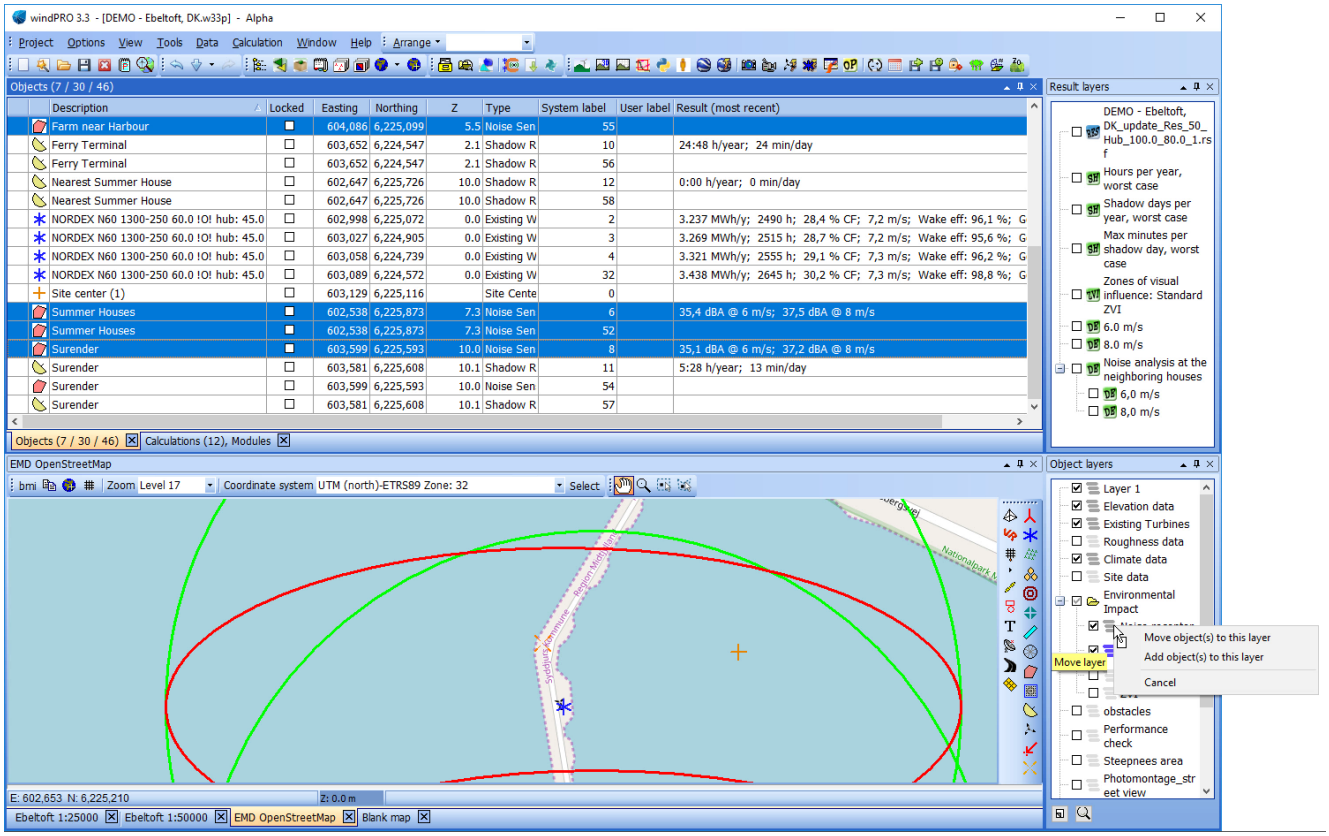
The difference, the ratio or a formula can be applied between two result layers. An example of a formula is IF(A>B;0,0;1,0) which means that the compare layer returns 0 if A is greater than B and 1 if the contrary. For each grid cell the calculation is processed and returned in a new layer. The resolution of this compare layer can either match the resolution of A or B or be user defined. The size of the area to compare is by default set to the overlap area between the two result layers but can also be user defined. The compare layer can be displayed and exported just like a normal result layer.

2.11.4 Objects layers

2.11.4.1 Objects layers - move or add objects

This can be done in three different ways:

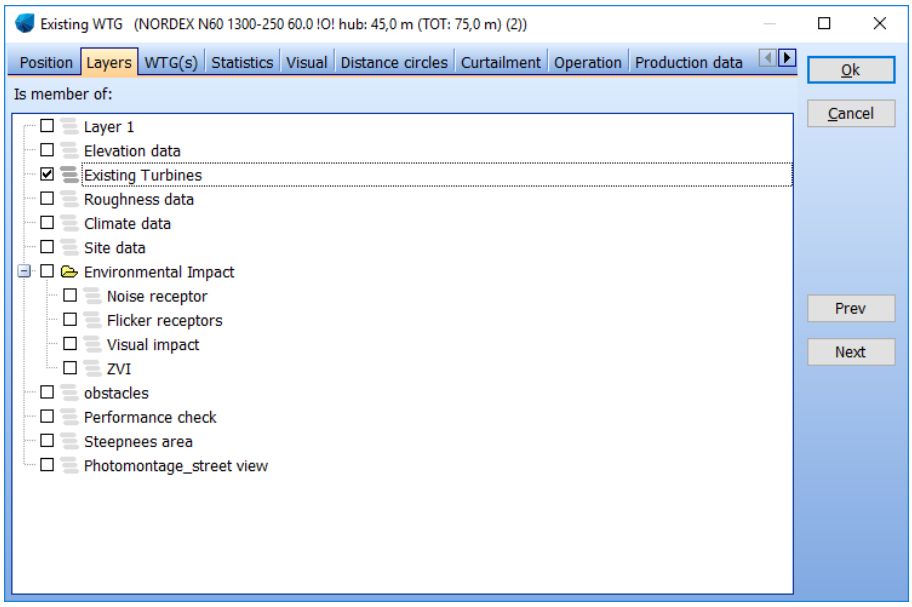
1) Drag the selected objects you want to move or copy from the Object List to a layer in the Layer Manager. windPRO will then ask whether you want to move or add them to the layer. When adding objects to a layer, a duplicate set of objects is not created on the second layer. The objects are merely assigned to both layers. If you want to duplicate objects, use the clone or copy function.



In the figure above, WTGs are selected (click on the first one with the left mouse button, hold down the <Shift> key and click on the last one or use as here the <Ctrl> key to select). Hold down the left

mouse button and drag the selected objects to the required Layer. The program will ask whether you want to “move” or “add” them to the layer. If added, they will exist in the original layer as well as in the new one.

2) In the Object Properties, you can assign the object to one or more layers.



3) Use the Show matrix option from the right click within the Object layer window (See Matrix view, magnifier, and move layers)

2.11.4.2 Object layers - organize objects

windPRO supports many ways of organizing objects in the layer structure. Here are a few examples:

a) Different object types for each layer
It’s often difficult to "select" on object, e.g. a noise sensitive area beneath a shadow recipient. This can be avoided by organizing all the noise sensitive areas in one layer and the shadow recipients in another. You can now make the final adjustments to the placements with one active layer without interference from the other objects.

b) Several different layout alternatives for one WTG project

Here it would be natural to organize each layout in its own layer. All the basic objects such as Terrain Elevation, Height Contour, Neighbors, Cameras, etc. could then be placed in Layer 1, or on their own layers. Each layout alternative has its own layer which makes it easy to quickly see and compare the different alternatives for an evaluation. When adjusting a given layout, only one layer is visible at a time so you don't risk modifying other alternatives when moving the WTGs on the map. All layout layer can also be organized into a Layer Group (e.g. called "Layouts").

c) Photos for visualization with different focal lengths
If, for a visualization, you have photos with different focal lengths, but taken at the same location, the Camera Objects will be placed on top of each other on the map and will be difficult to work with. Assigning each Camera Object to a separate layer is an easy way to work around the problem.

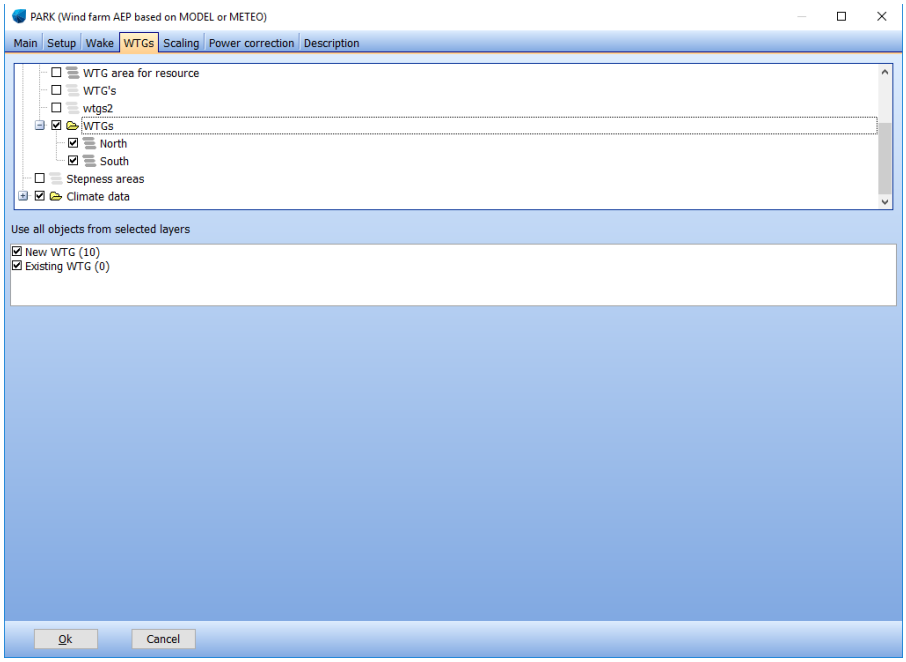
d) Line- and Area Objects disturb the overview
The map overview becomes cluttered if you have digitized many objects such as roughness, contour lines, areas, etc. If the various information is organized in layers, it's faster to activate or deactivate the layer than to find the individual objects in the Object List and then deselect **Show lines** etc. Once the TIN has been calculated, any terrain layer can be turned off and the TIN will not be removed (i.e. all objects will retain the calculated Z values).

e) Several projects in the same area
If you work with several projects within a limited geographical area it's possible to re-use much of the data and take advantage of working with many WTG projects in one windPRO project. Information relating to each project is placed in its own layer, while all joint objects are placed in a "joint-layer", e.g. Layer 1. This is especially important for Cumulative ZVI calculations where cumulative projects need to be on different layers (See Chapter 6, section 6.3.4).

f) For planning purposes
When a municipality for instance, is planning its WTG policy, they may want to organize the existing WTGs according to expected decommissioning time or prioritized removal, for example. It's also possible to place new WTGs in different layers according to different development alternatives. Subsequently, it's very easy with the layer structure, to combine different decommissioning and development alternatives and to perform different environmental calculations such as a ZVI calculation.

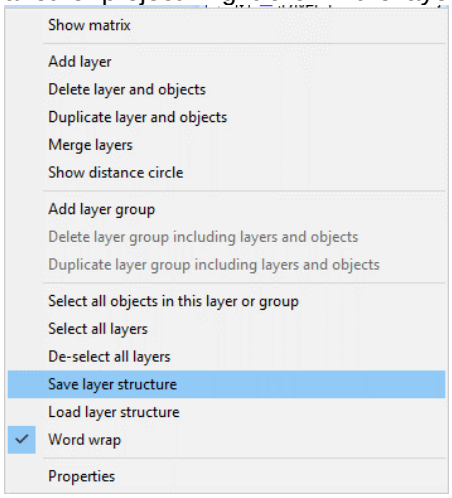
2.11.4.3 Usage of the layer structure in a calculation

When starting a calculation, it's possible to include WTGs from selected layers only for the calculation. You can deactivate single WTGs within each layer. Essentially, it will be much faster and more efficient to work with different alternatives in the same project.



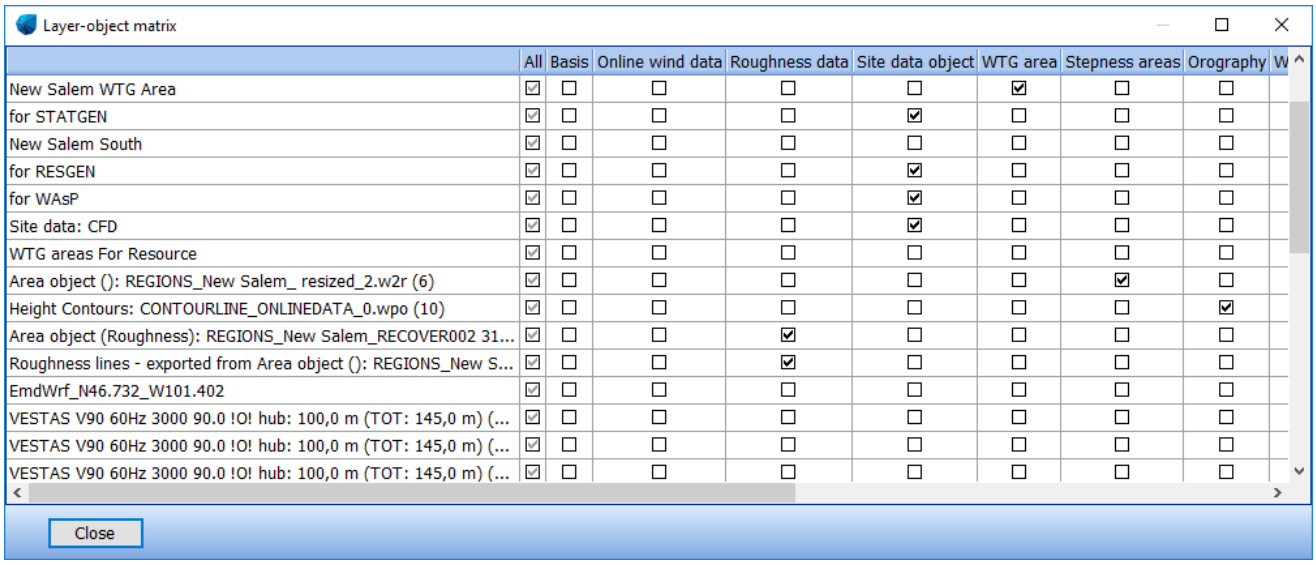
2.11.4.4 Save/load layer structure

A layer structure can be saved or loaded, which means that a good layer structure can be reused in another project. Right-click in the layer window and get the menu below. Select **Save layer structure:**

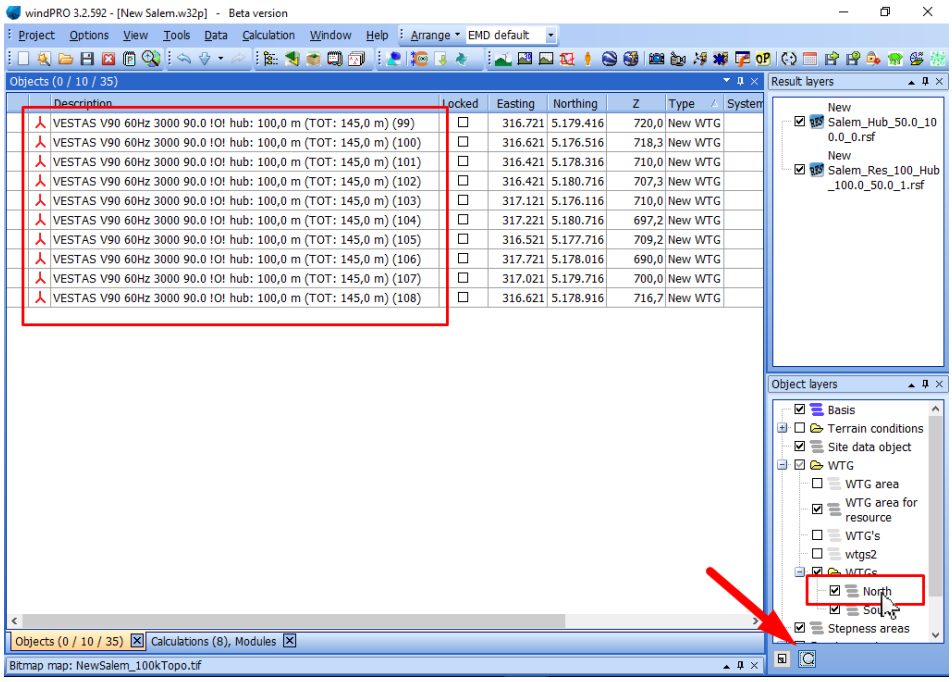


2.11.4.5 Matrix view, magnifier, and move layers

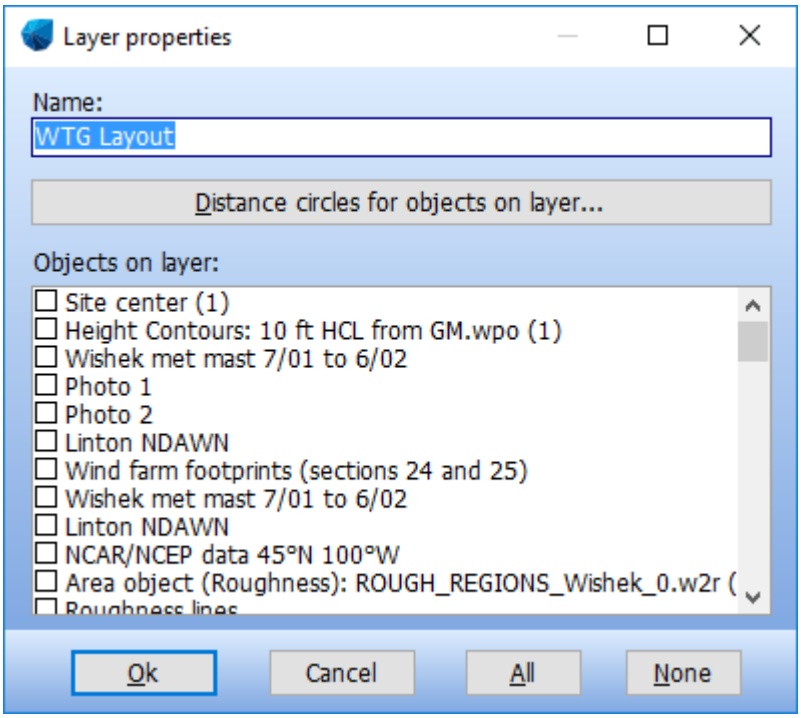
Note the **Show matrix** item in the right click menu above, which allows you to see a complete overview of all layers and objects that are assigned to them (see example below).



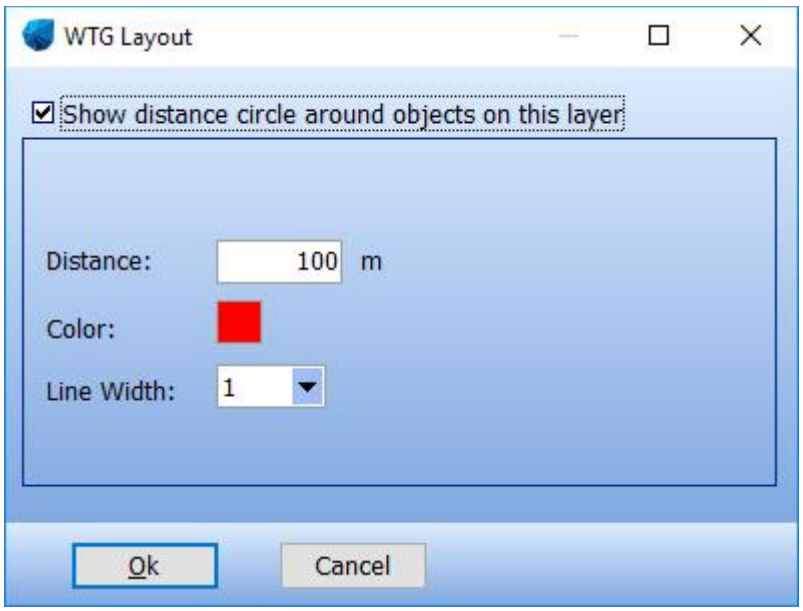
When the magnifying glass is activated (toggle by clicking on it), only the objects in the layer that you hold the cursor on will be shown in Object List. This can help you get a quick overview on which objects belong to which layers. Lastly, you now can move layers simply by dragging them with the left mouse button down.


windPRO 3.2.592 - [New Salem.w32p] - Beta version
Project Options View Tools Data Calculation Window Help Arrange EMD default
Objects (0 / 10 / 35)
Description Locked Easting Northing Z Type System
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (99) 316.721 5.179.416 720,0 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (100) 316.621 5.176.516 718,3 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (101) 316.421 5.178.316 710,0 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (102) 316.421 5.180.716 707,3 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (103) 317.121 5.176.116 710,0 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (104) 317.221 5.180.716 697,2 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (105) 316.521 5.177.716 709,2 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (106) 317.721 5.178.016 690,0 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (107) 317.021 5.179.716 700,0 New WTG
VESTAS V90 60Hz 3000 90.0 !O! hub: 100,0 m (TOT: 145,0 m) (108) 316.621 5.178.916 716,7 New WTG
Objects (0 / 10 / 35)
Calculations (8), Modules
Bitmap map: NewSalem_100kTopo.tif
Result layers
New Salem_Hub_50.0_100.0_0.rsf
New Salem_Res_100_Hub_100.0_50.0_1.rsf
Object layers
Basis
Terrain conditions
Site data object
WTG
WTG area
WTG area for resource
WTG's
wtgs2
North
Stepness areas

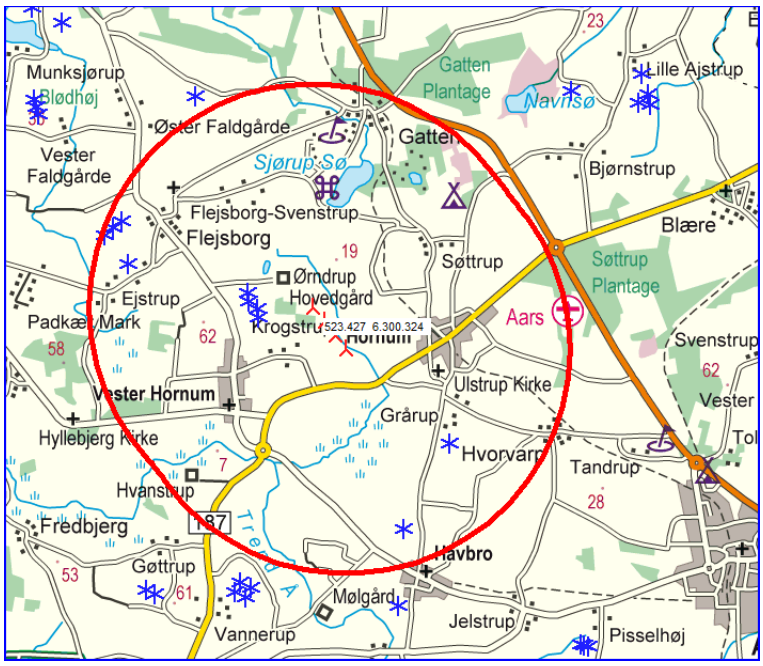
2.11.4.6 Distance circle around layer objects



The button **Distance circles for objects on layer** gives access to following:



Here the distance, color and line width is set. In Denmark e.g. there must be a special investigation if wind farms are established closer than 28 Rotor diameters to existing turbines. This is quickly investigated with distance circles. Please note that this tool draws a combined circle around **all** objects on the layer.



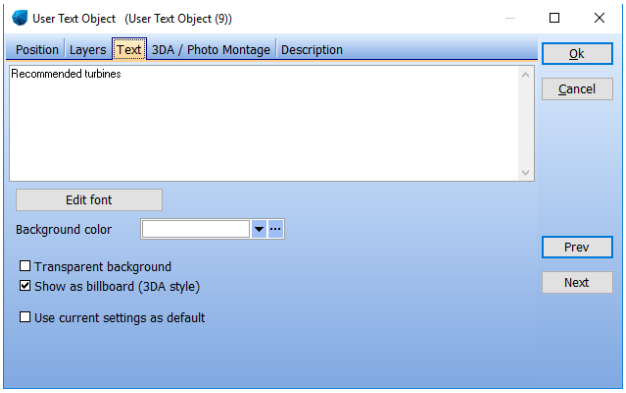
A 28 x rotor diameter distance circle around the new proposed project shows which existing turbines are too close.

2.12 BASIS – Text, ruler and Shape Object (profiles)

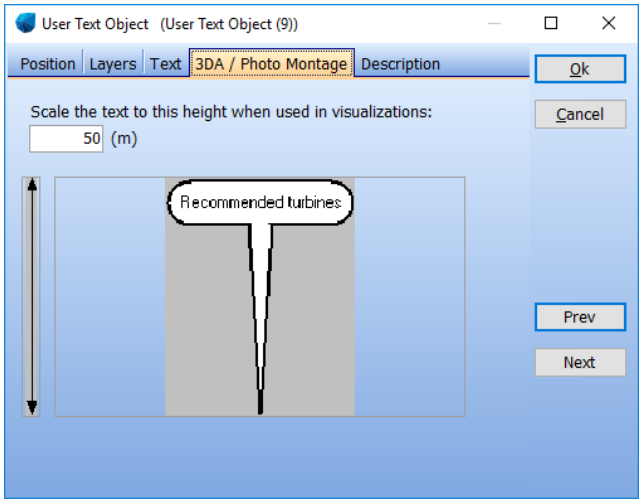
2.12.1 Auxiliary objects

windPRO also has a group of objects that are not directly involved in calculations, but are very helpful for designing, measuring and presentation.

2.12.2 BASIS - Text Object



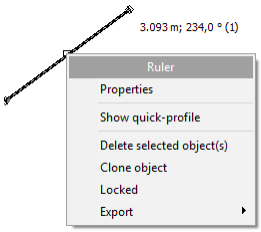
With the Text Object, you can attach text to the project map and later include it on the map printed in one of the calculation reports. You simply select the Text object from the Object Bar and place it on the map and then enter the text. You can move or edit the position of the text exactly the same way as with all other objects.



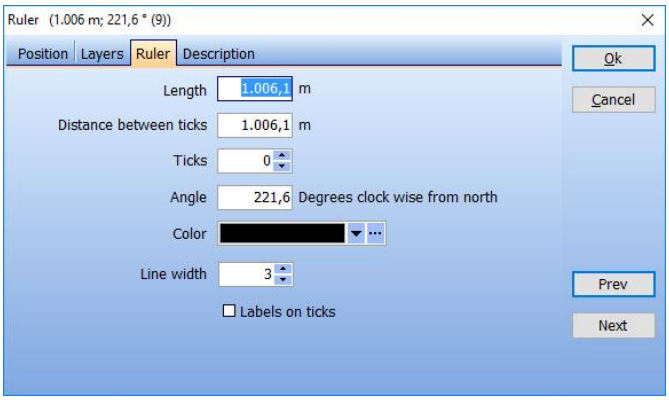
The Text Object can also show “balloon text” on maps, as well as in Photomontages, so that a specific location can be identified on map, on photo, or in the terrain model.

2.12.3 BASIS - Ruler Object

With the Ruler Object you can measure distances and bearings on the map. You select the button shown above from the Object Bar and place it on the map at the location where you want to start the measurement. You can use the <CTRL> button to lock the end of the ruler to a specific object. Then you click on the location where you want to end measurement. Hovering with the cross hair over the measurement will cause the distance and the compass angle to be displayed next to the ruler line. It's also possible to change the properties of the ruler. To do this, left-click on the line in order to activate it, then right-click and select **Properties** in the pop-up menu as shown below.



The following dialog box will now appear.



Here a fixed length or angle can be specified. The number of tick marks can be specified (e.g. to mark every 100 m distance) and the color and line width can be changed.

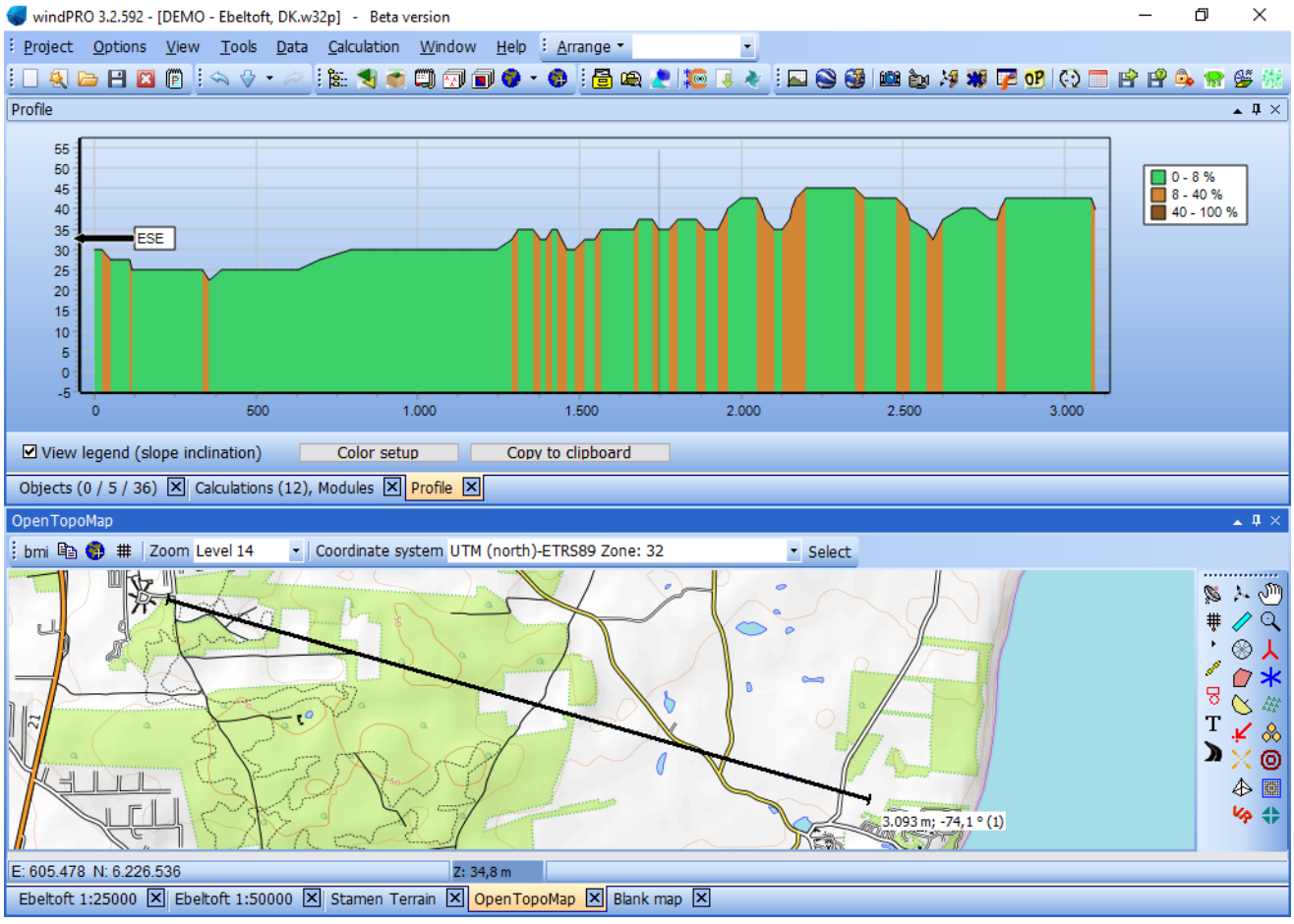
You can also move or edit the ruler line. Left-click on the line in order to activate it. Place the cross hair inside the center mark, then left-click and drag to move the ruler parallel to its original position.

Place the cross hair inside an outer mark to rotate the row around the opposite outer mark. Hold down the <Shift> key while dragging an outer mark to change the ruler length.

Lastly, you can measure a distance without creating a new Ruler Object. Simply create the ruler with left mouse button, but instead of finishing with a second left-click, use a right-click and the ruler will not be created.

2.12.3.1 Quick profile, based on Ruler object

This button (at the top toolbar) activates the profile after inserting a ruler; found in the right-hand toolbar.



*Create a ruler one the map and right click, choose **Show Quick Profile** from the toolbar and a cross-sectional view is shown along the ruler line. Note: this tool uses the actual contour lines, the alternative "rendered" terrain profile based on the shape object, using the TIN.*

The colors shown are pre-defined:

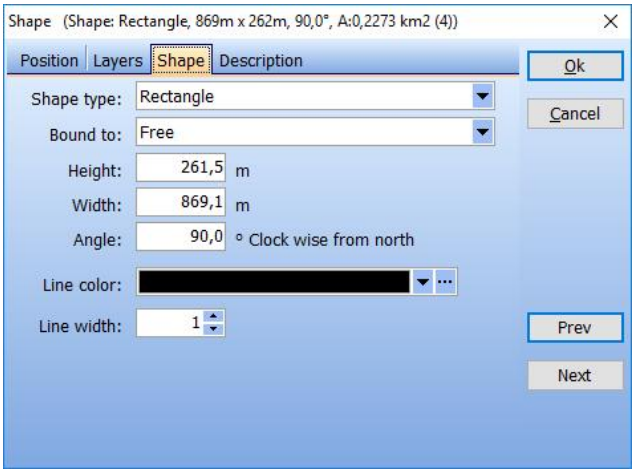
- Green < 8°
- Orange 8° - 17° (installing or transporting turbines may not be possible)
- Brown > 17° (flow separation or WAsP model problems may occur)

With the **Color setup** button the colors and values can be user defined.

2.12.4 BASIS - Shape Object (also Grid lines)

With the Shape Object, rectangles, squares, circles, or a grid can be placed on the map as a helpful tool for measuring. Select the button shown above from the Object Bar and place it on the map where you want one of the corners of the rectangle or square to be located. You can also use the <Ctrl> button on inserting to lock to another object (e.g. the Site Center or a WTG). Then mark the location of the opposite corner. For a circle, the two corners define the square of the inscribed circle. When the Shape Object is used as a grid, the object can be placed anywhere. Note that it is also possible to create a grid from the top bar of the map window

The shape object as rectangle is basis for terrain profile rendering, see below



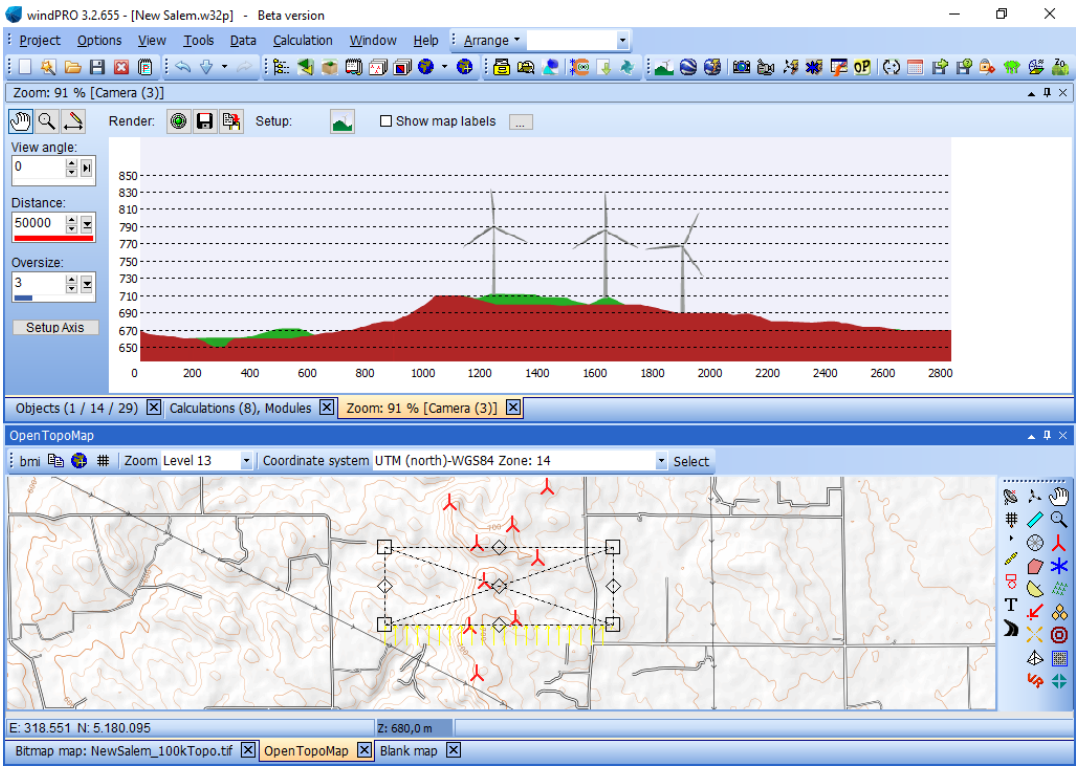
After selecting the second corner, the dialog box shown above appears. Here the shape type, size, angle, color, and line width are defined.

The size, angle, and location of the shape can also be edited on-screen. Left-click on the Shape Object in order to activate it.

2.12.4.1 Terrain Profile - based on shape object

Using the Shape Object (right Object Bar) you first create a rectangle to define the profile cut for which you want to view the terrain profile.

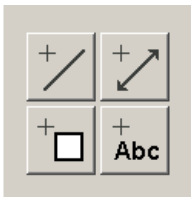
The Terrain Profile tool is activated with the Terrain Profile icon (top bar) or in the Tools menu. Note that there must be a TIN calculation based on a Line Object with height contour lines in order to use the Terrain Profile tool.

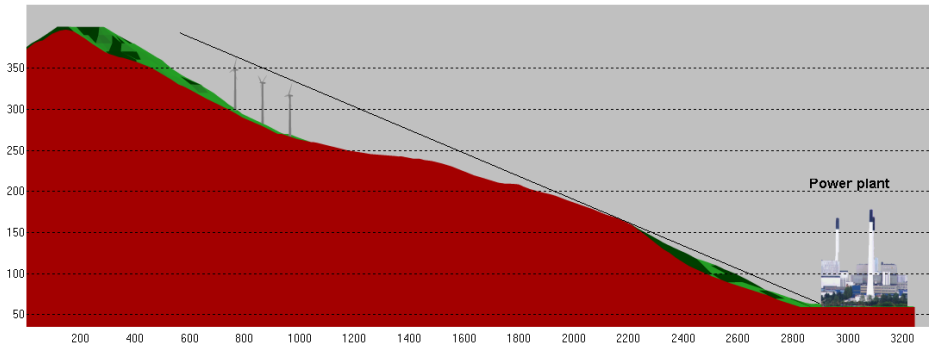


When you click on the Terrain Profile icon, a terrain profile for the selected profile-cut rectangle is rendered. The yellow arrows indicate the viewing direction for which the profile is being shown. The profile is always seen from the longer side of the rectangle. In order to view the terrain profile from the opposite side, the rectangle object must be rotated 180° by dragging the corners.

The terrain profile can be over-sized and stretched, or just over-sized. The difference between stretching and over-sizing will be in the way that objects such as WTGs are shown on the terrain profile. If stretched, all objects shown will be stretched in the over-sizing operation. If “stretch” is not chosen, the objects, such as WTGs, will simply be over-sized both horizontally and vertically. This makes it easier to see the WTGs in the terrain profile, but it will also oversize them in the horizontal direction.

With the Draw Tool shown above, which is found in the tool menu at the top of the Terrain Profile window, lines can be drawn and text can be added to the profile view. Additional tools are available as described below.

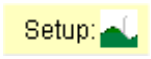




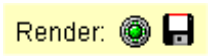
The graphic above illustrates how a bitmap (the power plant) is inserted as a 3D Object and three WTGs are inserted on the hill. The profile and the objects are all oversized by a factor of 3. The line from the power plant over the edge of the hill illustrates that from the left base of the power plant the WTGs will not be visible (**Note**: This view does not account for Earth Curvature).

The part of the hill shown in red is that which would be seen on the near side of the profile-cut rectangle. The part of the hill shown in green is that which would be seen from the far side of the profile-cut rectangle. The part of the hill shown in green can also be seen from the viewpoint.

The terrain profile is ideal for analyzing local conditions and can be used for many purposes. It is especially useful for illustrating proportions between the landscape, WTGs, and other elements.



Colors can be changed with the setup button.

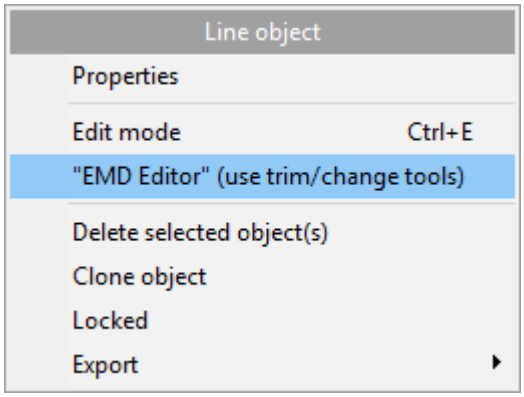


After any settings are changed, or any new objects are added within the terrain profile rectangle on map, the **Render** button must be clicked to update the image to include the new elements. Clicking on the floppy disc icon will save the terrain profile image as a bitmap. There is no specific report that can be generated using the terrain profile. The bitmap image is the only possible result output.

2.13 BASIS – EMD Editor (line, area and grid objects)

2.13.1 EMD Editor for lines and polygons- trim and change data

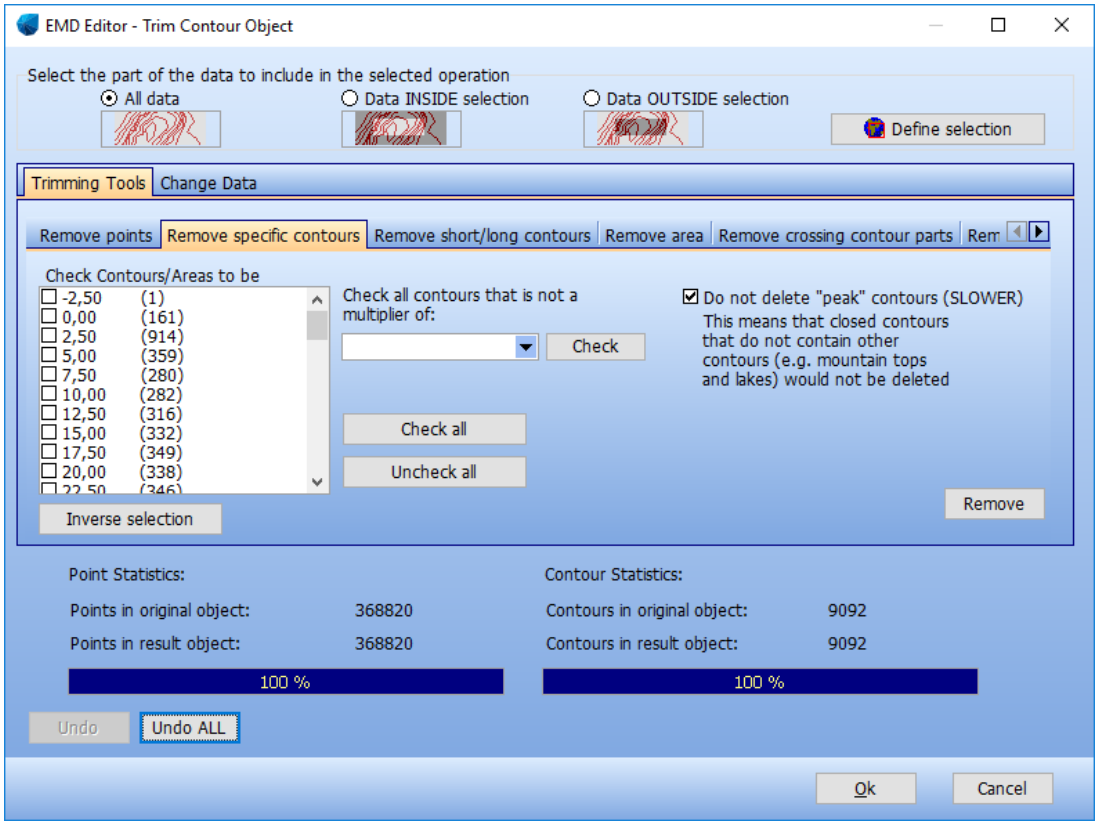
The EMD Editor works with data files associated with both Line Objects and Area Objects. A simple version is available from the elevation grid object. This is described separately at the end of this section. Often the data files hold far more points than needed, or they may be misplaced on the map due to digitizing in the wrong coordinate system, or they may simply contain errors, possibly from converting from one file format to another.



The EMD Editor is started from the right-click menu on the Line, Area, or WTG Area Object. If the object is in Edit mode, the Trim menu cannot be selected. The editor can also be started from the Line or Area Object window.

There are two main groups of tools: Trimming and changing data.

2.13.1.1 Trimming tools



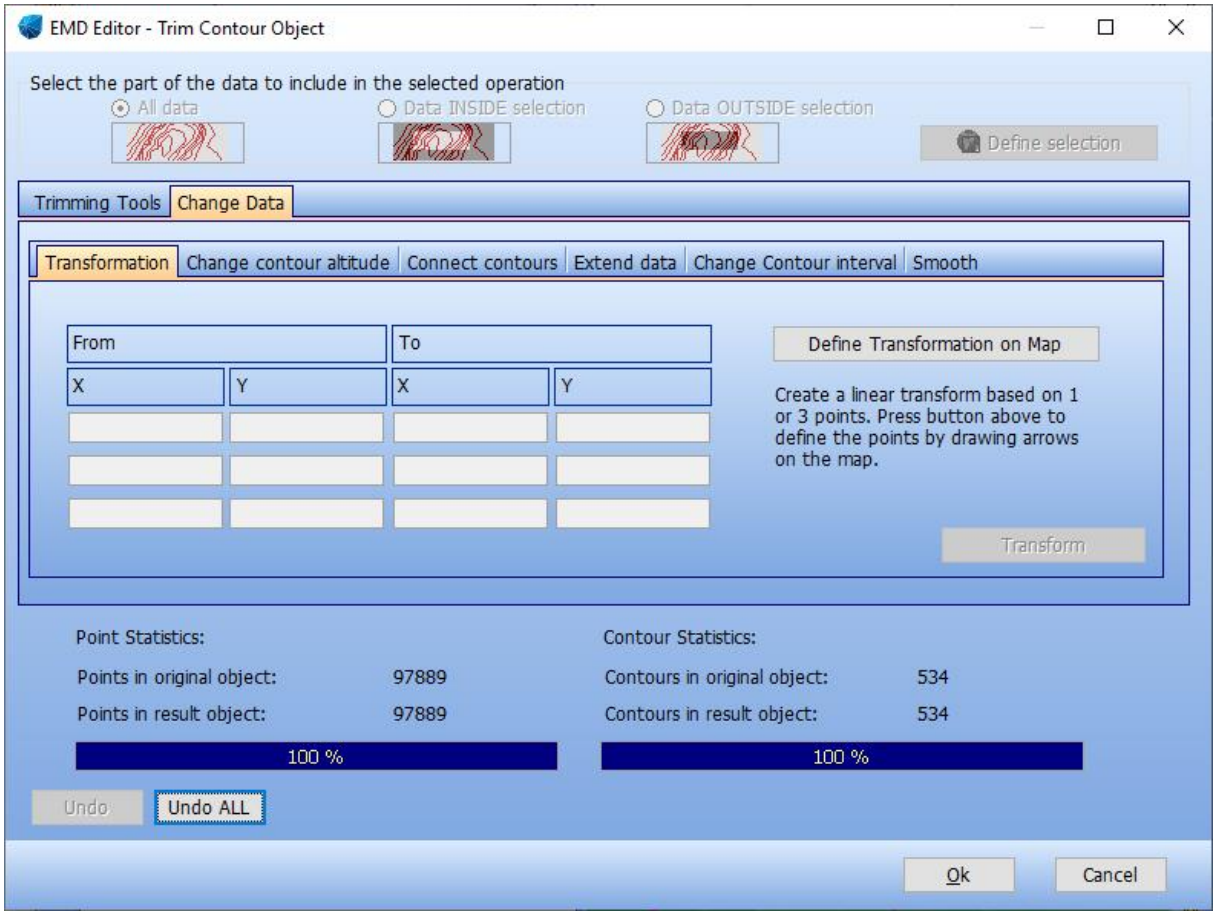
Trimming tools are typically used for removing points or lines or parts of a region to reduce the amount of data.

There are eight main Trimming Tools and each is explained in detail on the respective tab sheet:

- Remove points
- Remove specific contours
- Remove short/long contours
- Remove area
- Remove crossing contour parts
- Remove duplicated data
- Remove “No TIN” data

- Remove Orphan data

2.13.1.2 Change data



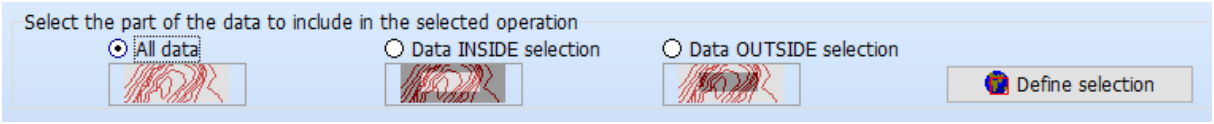
Change data tools are used for moving, scaling, adding or converting data, or simply manually changing of a group of data.

There are six main Change Data tools and each is explained in detail on the respective tab sheet:

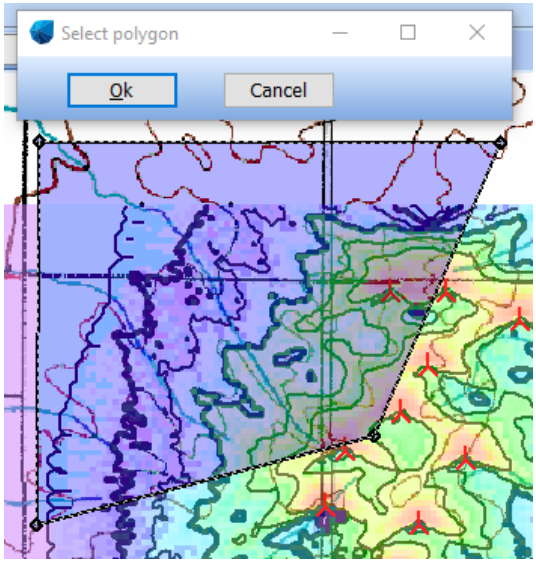
- Transformation (move, rotate, or twist data to correct for digitization errors, e.g. digitizing based on local or wrong coordinate system or datum). The transformation can be made graphically, where either 1 or 3 arrows on the map are dragged so the “from” and “to” points are shown, indicating the coordinates for the transformation.
- Change contour altitude (user-specified conversion formula to change from e.g. feet to meters).
- Connect contours (spline) –connect separate contours of the same value.
- Extend data – add more data outside of the current data to extend the area covered
- Change Contour interval – change from 10m to 5m for instance
- Smooth – smooth contours to reduce harsh changes of direction.

2.13.2 EMD Editor for grid data - remove data

In the current version of windPRO, a basic editor for gridded data is available. It is loaded from the objects **Data** tab, with the button **Edit layer**.
When started, one feature **Delete data** is found.



First decide whether the data inside or outside a later selected area will be deleted.

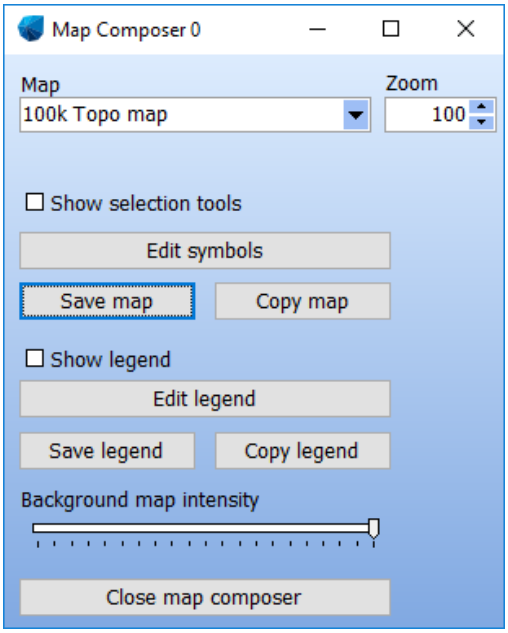


Then select the area. Note that a free polygon can be defined, starting with 4 corner points. These can be dragged, and right clicking on the lines between the points allows you to insert points. Right clicking a point gives you the option to remove the point.

2.14 BASIS - Map Composer

2.14.1 Start the Map Composer

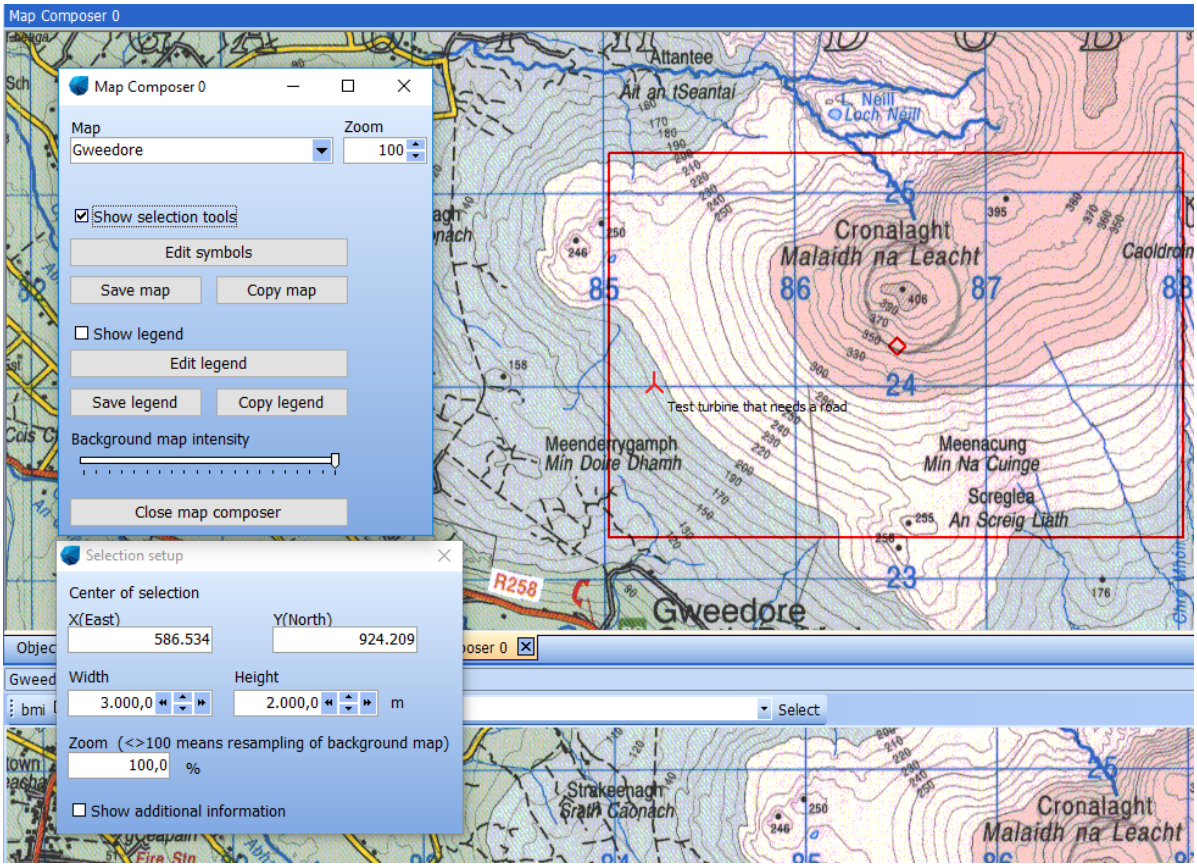
The Map Composer is used to prepare maps for use in reports. It allows users more control of the look and content of the maps. The Map Composer is started from the top tool bar by clicking on the button shown above.



Starting the Map Composer opens a split window containing the map (where the design of the composed map can be viewed), and the Map Composer Control window. The map composer window is not to be confused with the normal map window.

The Map Composer Control window has following options:

A name can be entered in order to find the map setup later. Different maps with different elements, scales, or symbol configurations can each be stored with a different name. The default is “Map Composer X”, where X is a number, starting with 0.

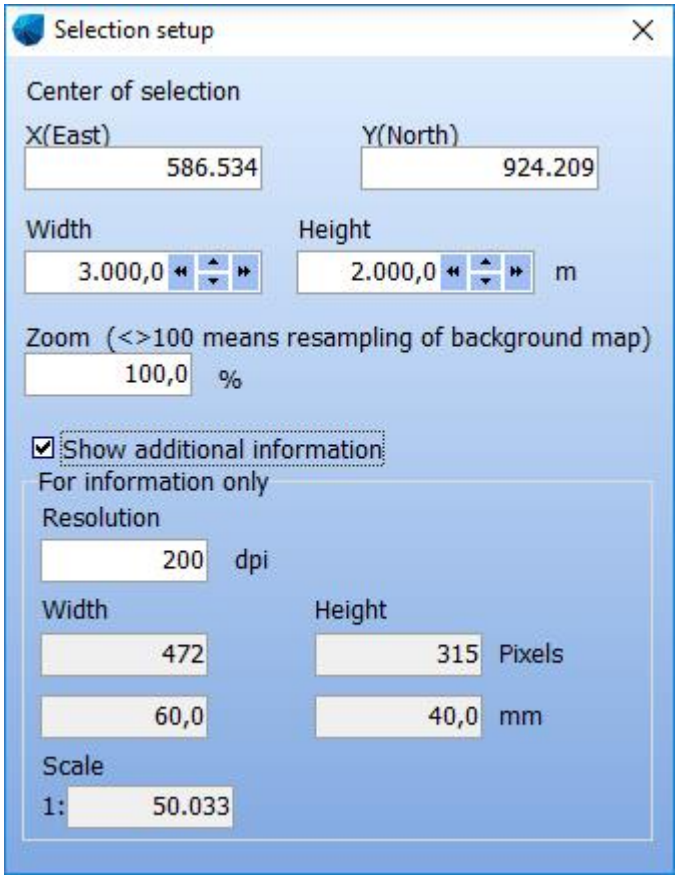


When the Map Composer option **Show selection tools** is checked, you can drag the square defining the part of the map that is to be copied to a report. This can also be specified exactly by specifying the coordinates, size, and zoom level.

With the option **Show additional information** you can specify a graphic resolution in dots per inch (dpi), which is important for reports that must be printed with high graphic quality.

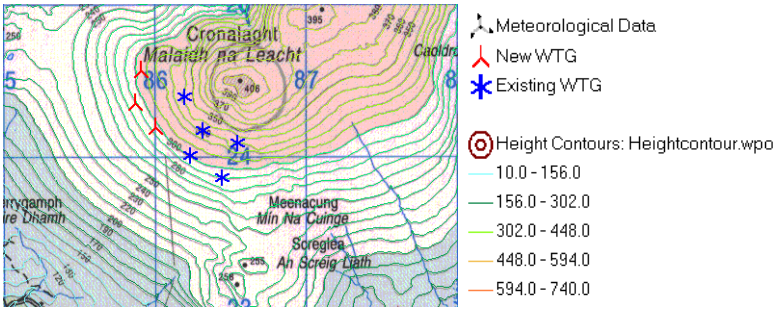
2.14.2 Select map portion and resolution with the Map Composer

Changing the resolution will change the size of the graphic in millimeters. If you specify a resolution (dpi value), the resulting width and height of the image as it will appear in the report are displayed.



If you want to show a larger map area while maintaining the size and resolution (dpi value), the zoom must be adjusted. The map will be resampled in order to fulfil your requirements.

In the example above, a 3 km x 2 km portion of the map is selected. For a 200 dpi map, an area that is 60 mm x 40 mm will be required on the report page. The scale will then be 1: 50.033 (it should actually be 1:50.000, but a slightly inaccurate coordinate setting makes the difference).

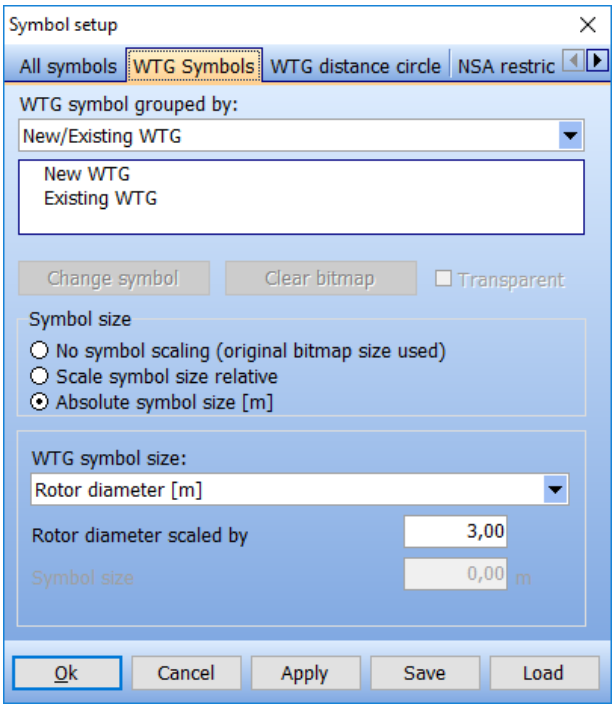


Above, the map is copied to the clipboard, and then in Word, the height is set exactly to 40 mm so that the map will print at a resolution of 200 dpi and a scale of 1:50000.

Shown above is an example of an ordinary screen dump (print screen), without the Legend, which can be added by clicking **Copy legend** in the Map Composer Control, and then pasting it into the Word document.

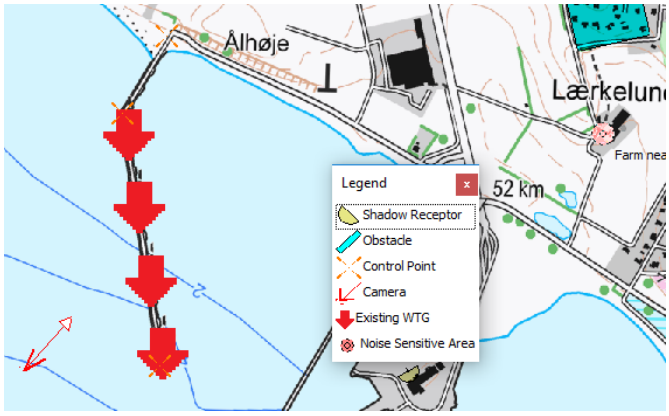
Note how the height contour lines have different colors for different heights (this is configured by a setting in the Line Object).

2.14.3 Symbol setup in Map Composer



One of the more useful features of the Map Composer is the one that allows you define custom symbols (mainly for WTGs), and to scale them according to the size of the WTG.

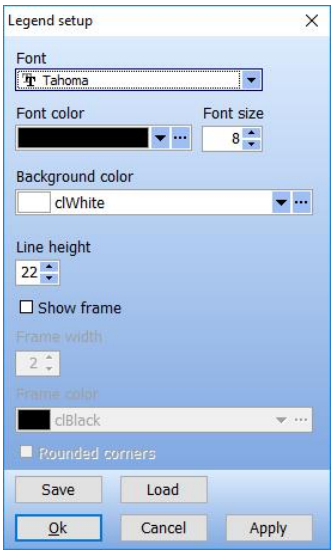
Any bitmap file can be used as a WTG symbol. Some examples can be found in the folder “windPRO Data\Standards”, but any bitmap can be used. A map example with different types of symbols for new and existing WTGs is shown below.



If custom symbols are defined, the legend will be updated with the new symbols. In the example shown above, the legend has been modified slightly, as the icon for Existing Turbine has been changed to a user-defined image (red arrow).

2.14.4 Legends and more options with Map Composer

The legend can be modified in numerous ways inside the Legend setup window shown below:

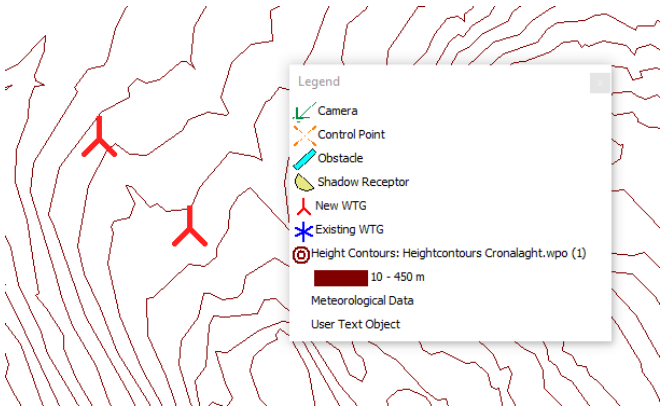


Font, background color, line height (the distance between lines in the legend), show frame, frame width, frame color, as well as rounded corners are the available options.

Lastly, shown below is an example which includes reduced background map intensity, symbols scaled by rotor diameter, labels, and the wind resource map from result layer.

The WTG symbols can also be divided by WTG type or manufacturer, which is illustrated by the legend for this example, with two different WTG types.

Note: The type of objects that appear in the visible layers will determine the appearance of the Legend, even though the objects may not be within the selected portion of the map.



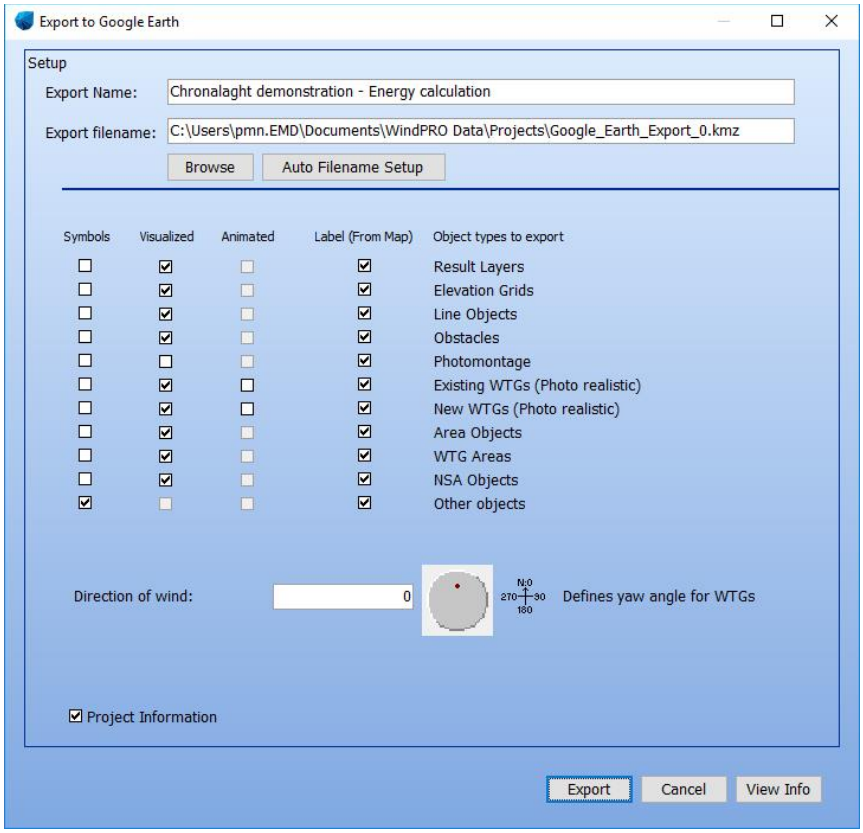
After designing your individual map layout, you can copy it and make another map based on the same parameters, while including additional elements, e.g. one map for noise, one map for flicker, etc. This allows you to make a template, no longer limited by the default symbols in windPRO, and then with the features you require, to copy the relevant elements to a professional report with uniform and high quality map presentations.

2.15 BASIS - Google Earth exporter

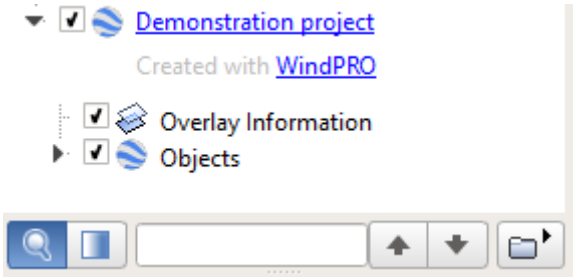
windPRO supports visualizations in Google Earth in two different ways. Either by synchronizing windPRO with the Google Earth viewer, or by exporting a .kmz file, which can later be loaded into Google Earth.

To synchronize Google Earth with windPRO, open the **Synchronize WP objects in Google Earth view** window from the **Tools** menu. Moving objects in windPRO will automatically move them in Google Earth. Note, this option currently works with versions of Google Earth Pro no later than 7.1.8.3036 (32-bit).

To export to a .kmz file open the **Google Earth export** window from the **Tools** menu. You can also export by right-clicking an object and selecting **Export** and then **Export to Google Earth kmz file**. When exporting to a kmz file or synchronizing the Google Earth viewer, you can decide what types of objects to include and how they should be shown:



You can choose how some of the object types will appear in Google Earth, including labels and animations. You can choose to hide project information by unchecking the Project Information checkbox.



*In the Google Earth layer structure, a windPRO export layer is added with subfolders with object information etc. Right click at the windPRO export and choose **Email** to send the Google Earth presentation to the chosen recipient's computer as a .kmz file. This file can also be saved in your project folder (right click on the layer and choose **Save As**) as part of the project documentation.*

When Google Earth is closed, the file will be removed unless you perform a manual "Save As" operation. This way you can "re-export" the project a number of times without getting your own Google Earth filled with several different layouts.

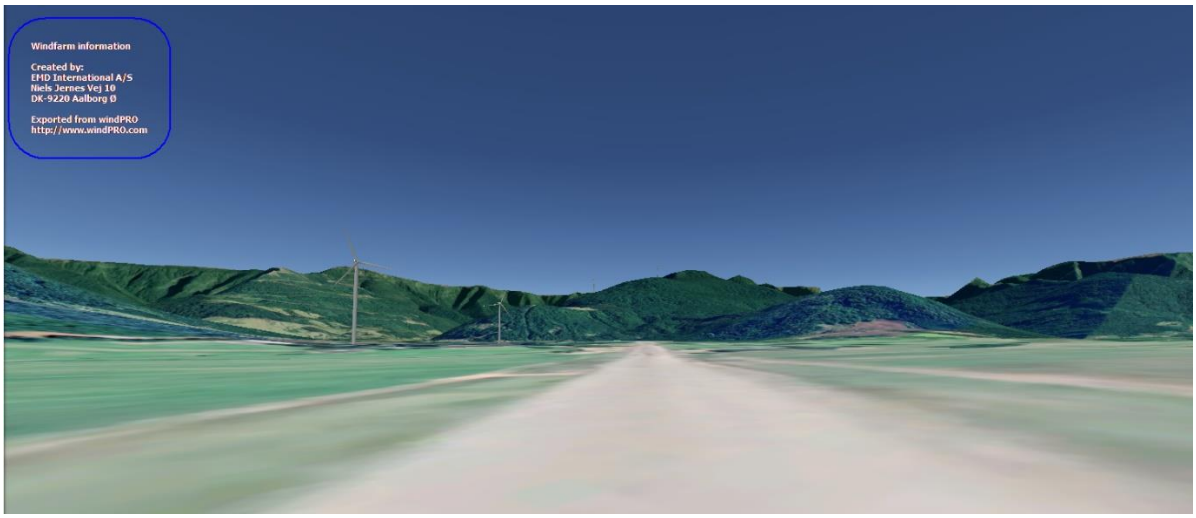
2.15.1 WTGs as photo realistic 3D objects

WTGs can be exported to Google Earth and shown as photo realistic 3D objects, just select the objects to export in object list and right click or click the Google Earth button.

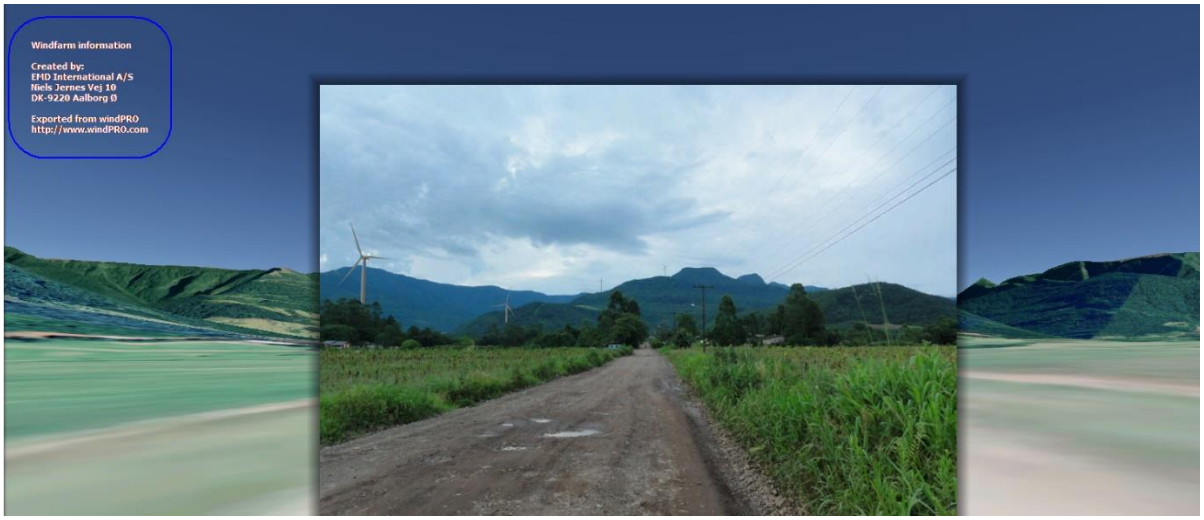
Example of a turbine in windPRO visualized in Google Earth

2.15.2 Photomontages as "fly in"

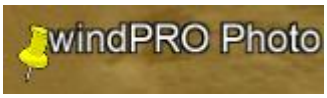
Exporting cameras can give a unique test of your photomontages and a unique exporting feature, so anyone with Google Earth access can see your photomontages on a Google Earth background.



Turbines exported to Google Earth.



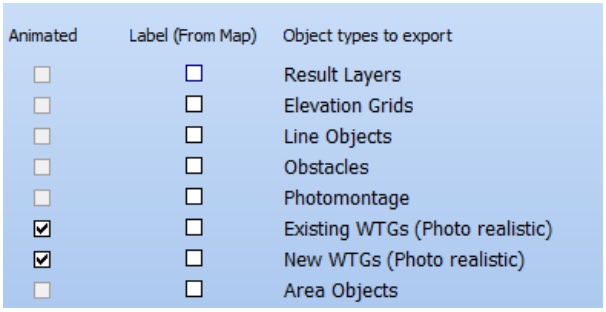
Including cameras in your .kmz export will show the photomontage in Google Earth.

When clicking on the pin 

in Google Earth, you can "fly in" and see your photomontage layered on top of Google Earth. Using the "transparency" slider in Google Earth, you can increase transparency of your photo and check how well it matches the Google Earth background.

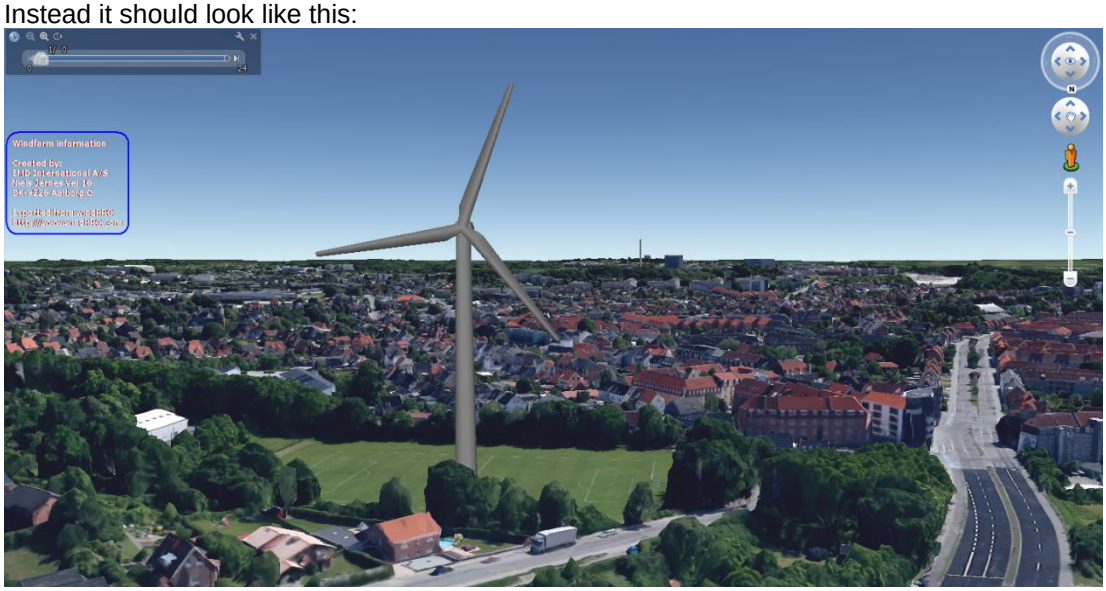
2.15.3 Animated WTGs in Google Earth

New and existing turbines can be animated when exporting to a .KMZ file to be opened in Google Earth. Check the **Animated** checkboxes in the Export to Google Earth window to activate.



When opening the .kmz file in Google Earth, make sure no other Google Earth overlays are active, as this can result in the turbines having too many blades because the same turbine is shown multiple times on top of each other. This effect can be seen below.

Instead it should look like this:



To start animating press the play button in the upper left corner of Google Earth.

To adjust the animation speed, open the animation setting via the wrench icon to the right.

2.15.4 Results layers and symbols as overlay

Result Layers exported to Google Earth will be draped on top of the Google Earth surface, ideal for wind resource maps, noise contours, etc. Simply tick the desired result type in the setup window.

Not all objects can be visualized in Google Earth, such as roads, radars, eGrid elements, etc. These will be shown with a symbol.

2.15.5 Embedding Google Earth in windPRO window

The embedded Google Earth viewer inside windPRO window is no longer available due to new policy from Google. However, it is still possible to synchronize windPRO with the external Google Earth viewer, as described in the beginning of Section 2.15.

2.16 BASIS - 3D Map view

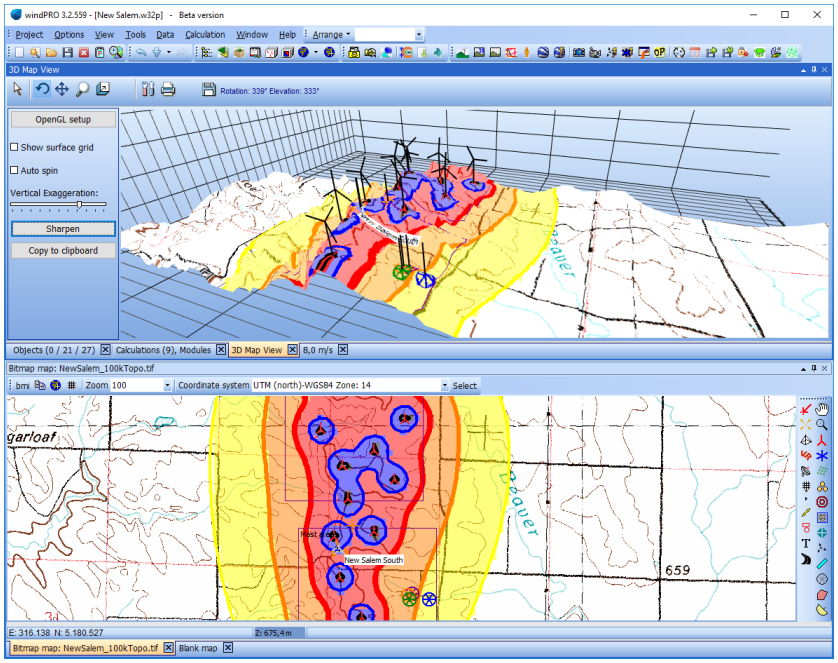
Clicking this button opens a window with the 2D background map draped onto a 3D elevation model. Any visible object on the 2D map is shown on the 3D map as a black stick, while the turbines are shown with three blades on to the stick. Any visible result layer is also draped.

When objects are moved on the 2D maps they will automatically be moved on the 3D map.

Viewing the map in 3D can be very useful to check the height contours, to understand the impact of the terrain on the wind resource, shadow, ZVI calculations etc.

The map can be rotated by dragging with the left mouse button pressed. Panning is done by dragging with the right mouse button pressed. Zooming can be done with the mouse wheel. These operations can also be selected in the top bar, along copy/print to export the image.

On the left side, it is possible to show the grid surface or to have the 3D map rotate. The vertical scale can be used to exaggerate elevation differences. Clicking the Sharpen button will increase the details of the 3D map, until the map is moved. It is recommended to use gridded elevation data for a faster and smoother viewing of the 3D map.



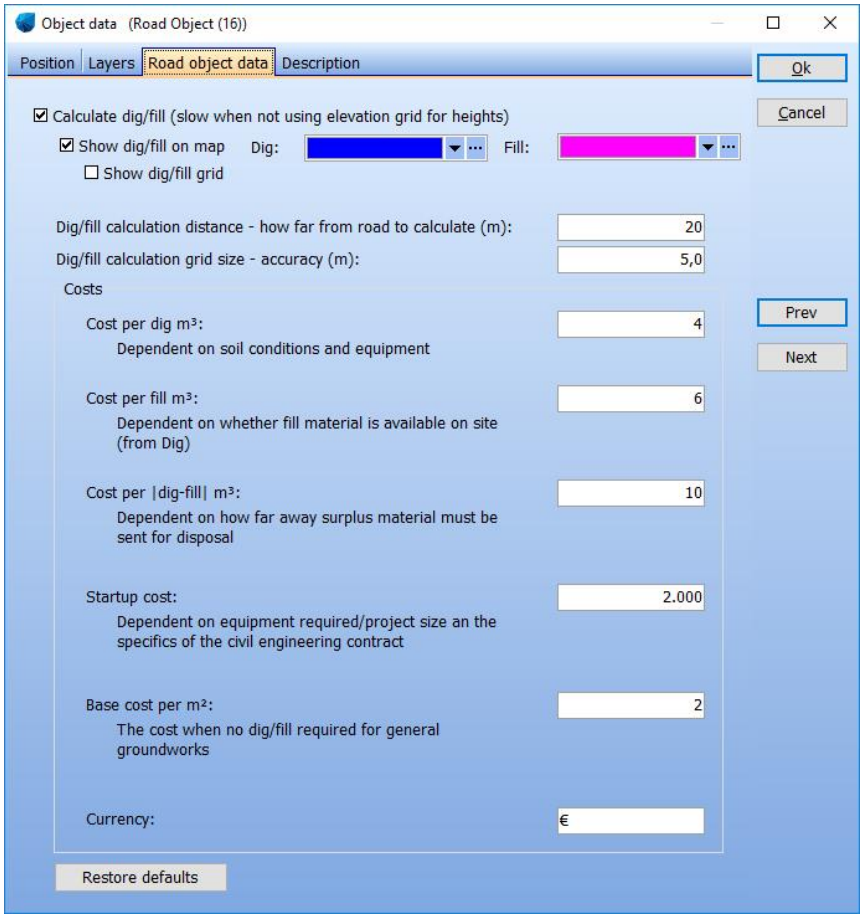
The 3D view is based exactly on the map part shown in the 2D map window. Having a relative wide map with little height as shown here gives a narrow 3D stripe. Enlarging the map view, e.g. by dragging this to a separate screen, gives better proportions.

2.17 BASIS – Road Construction

2.17.1 Introduction to the Road Construction tool

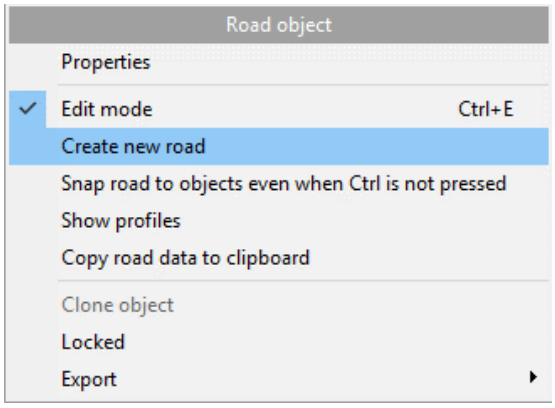
The windPRO Road Construction tool is a tool for assisting with the planning of roads when siting turbines. The access to a turbine often requires building new service roads and upgrading existing roads. The design of roads for a turbine must fulfil different demands, such as road width, horizontal and vertical curvatures, limited slope inclination and budget constraints. The Road Construction tool takes all these considerations into account.

With a click of this map symbol, a Road object can be added to the map. A road object can contain multiple roads sharing the same properties defined below.

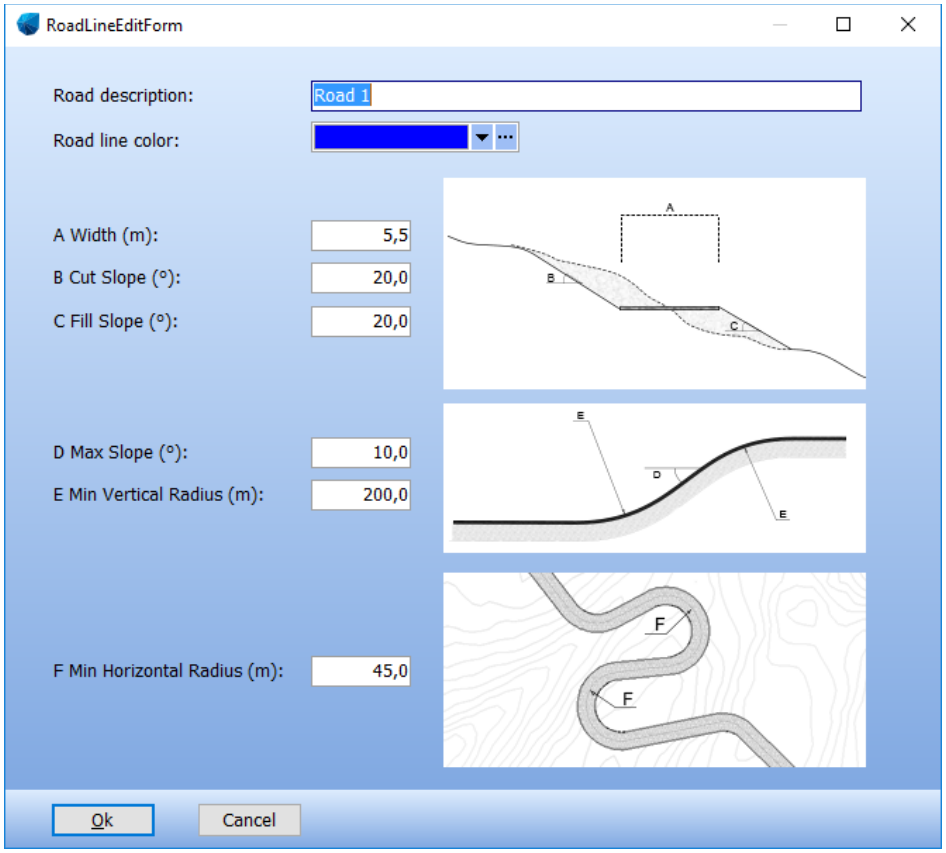


Properties of a road object. The different costs of, e.g., digging and filling can be specified here.

Once the road object has been created, it is in Edit mode and new road sections can be created and edited.



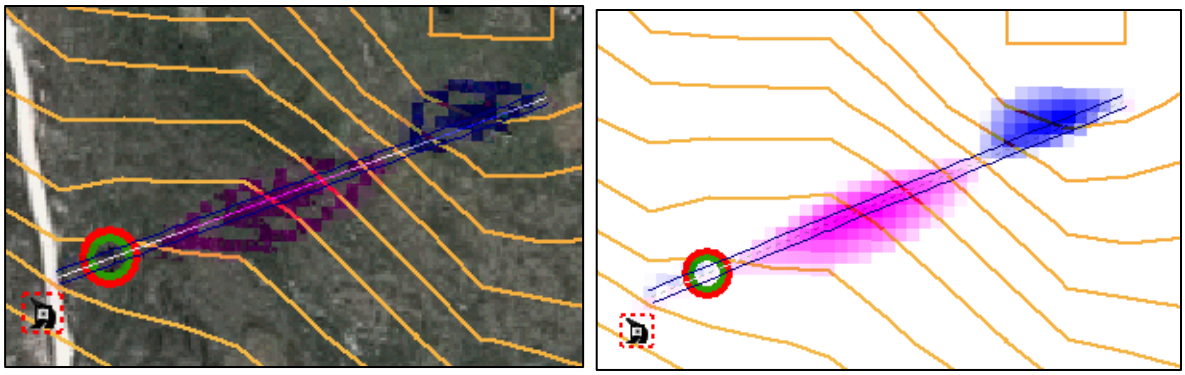
*While in Edit mode, create a new road section in the road object by right clicking the map and selecting **Create new road**. Multiple roads can be created in the same road object.*



When creating a new road section in the road object, the allowed thresholds for slopes and curvatures can be specified.

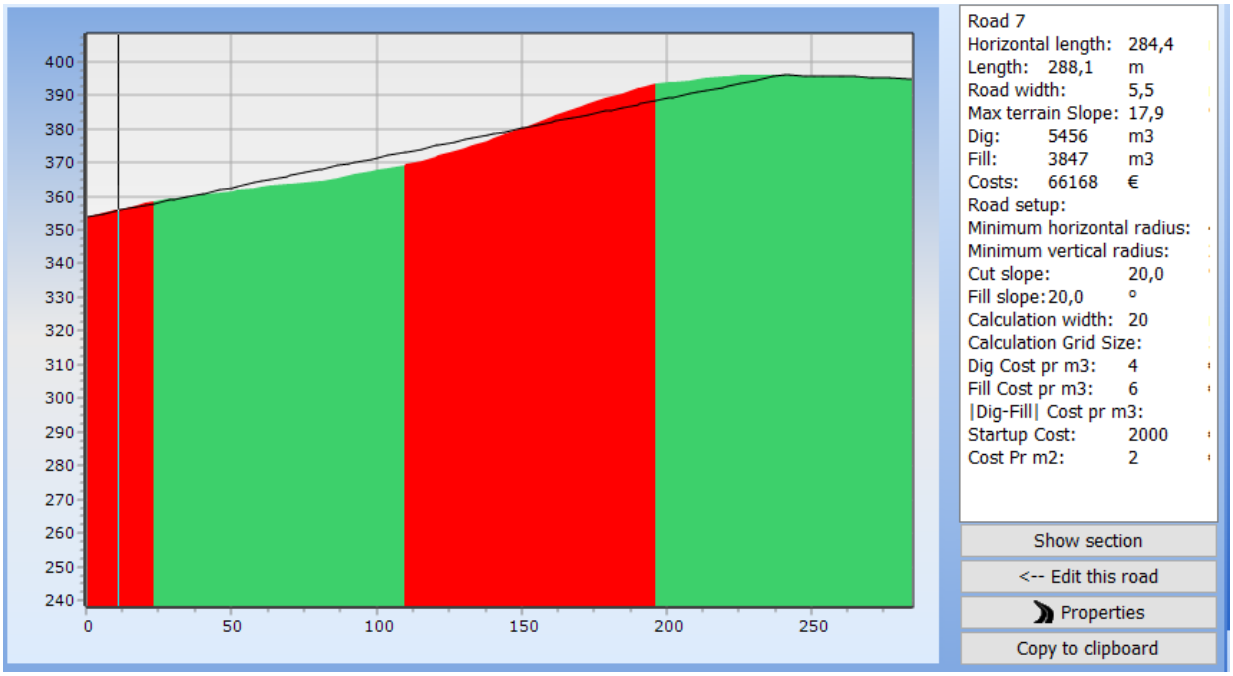
2.17.2 Dig and fill

The road construction tool takes advantage of the height data in the project to calculate the needs for digging and filling areas, thus leveling the road. If no height data is available, the terrain will be assumed flat.



When drawing the road, the required digs and fills for the road are shown in two colors (here digs are blue and fills are purple). The color scheme is user-defined.

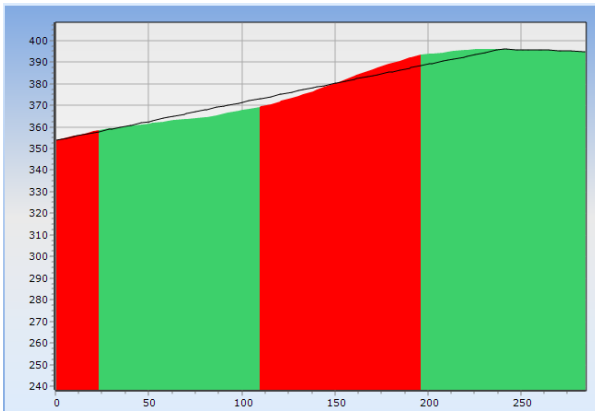
Besides showing the digs and fills on the map, the inclination of the road can be seen in the profile view as a black line (see below). The green part indicates where the terrain meets the slope incline threshold. The red part indicates where the terrain exceeds the slope inclination threshold. Thus, some parts require digging, while others require filling in order to fulfil the slope inclination threshold.



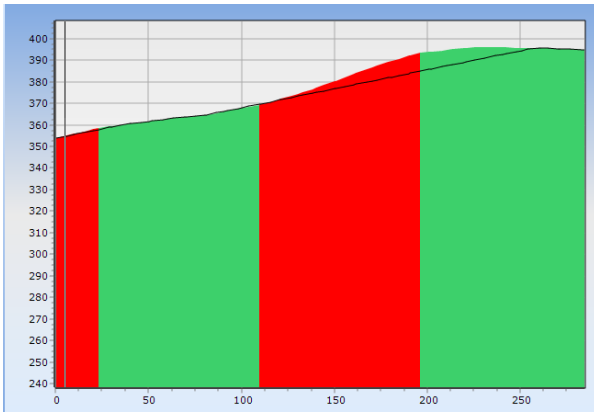
Profile view of the road

It is possible to shift the distribution of the road inclination by selecting **Less Fill** or **Less Dig**. If selecting **Less fill**, more digging will be required and vice versa. This way it is possible to adjust the cost of the road.

*Options below the profile view such as **Less fill** and **Less dig**.*



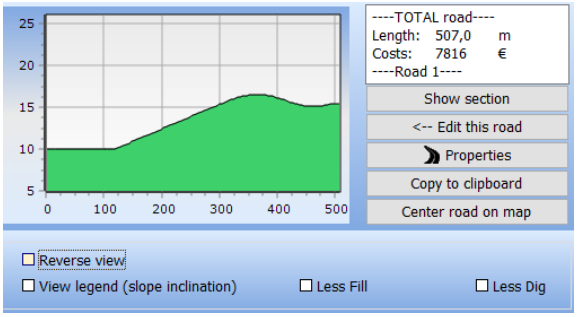
Default dig/fill distribution

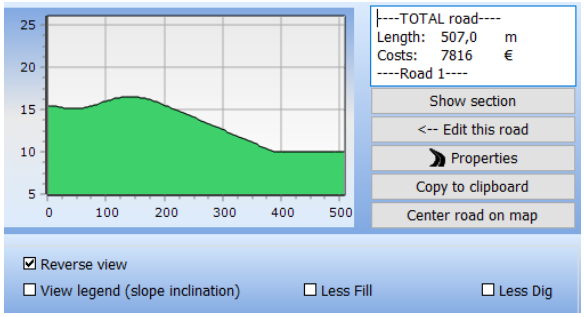


Less fill distribution

Profile view of the road using default dig/fill distribution (left part of profile) and less fill distribution (right part of profile).

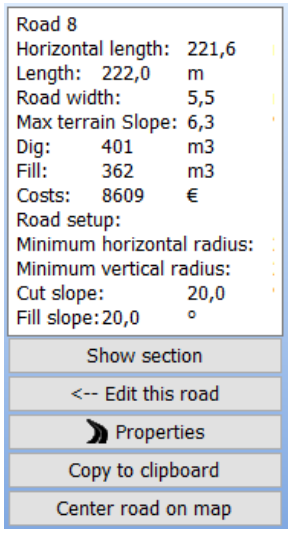
By default, the profile view starts from the position of the first road point (see below). The profile view can be reversed, so that the profile view starts from the last road point. This is done by selecting the **Reverse view** checkbox.





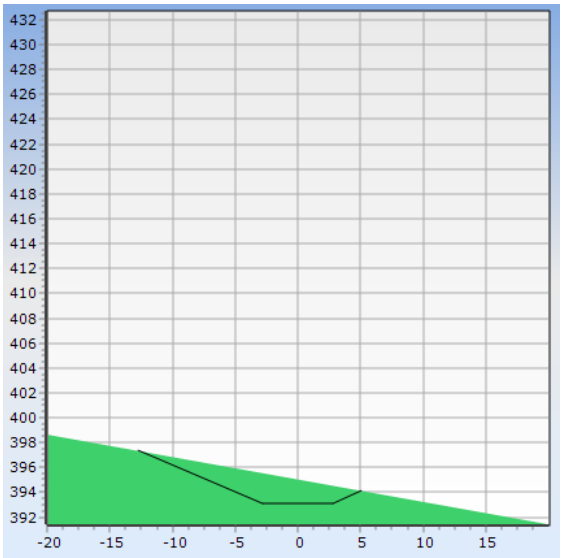
The direction of the profile view can be adjusted to follow the road from the first road point to the next (the first image), or first-to-last road point (the second image).

While designing the road layout, the costs are continuously calculated based on the cost input in the road object properties. The costs for the currently selected road section are shown next to the profile view along with information about road length and setup. Coordinates and other information about the road can be exported by clicking **Copy to clipboard**.



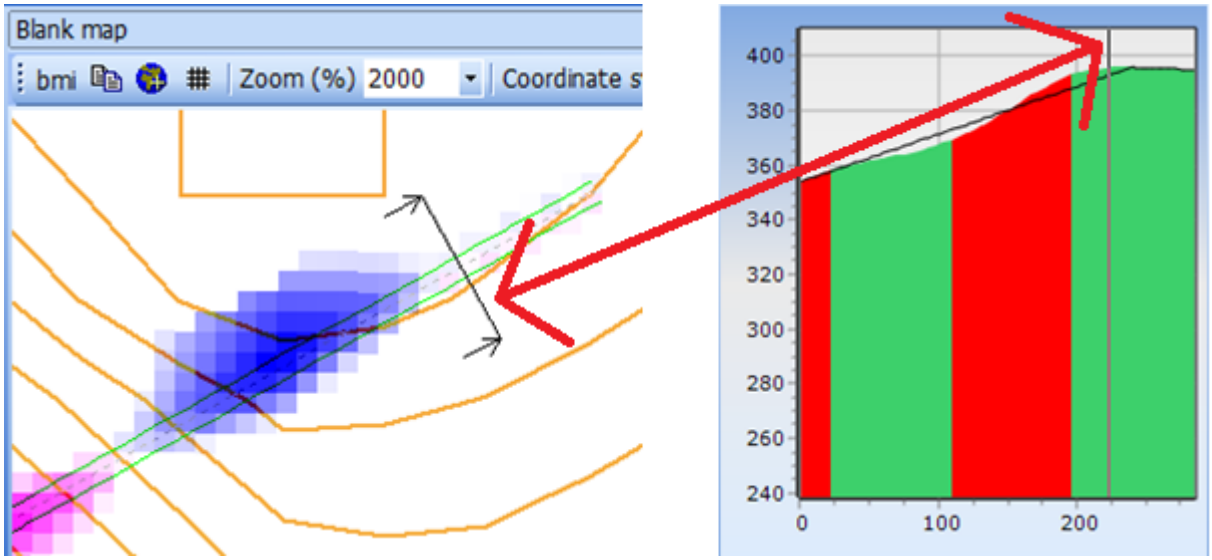
Information window showing road costs and setup. If any thresholds are exceeded, a warning will be displayed in the information window. This could be a slope being too steep, a bend too sharp, etc.

The cross section of the road can be activated by clicking **Show section** below the information window.



Section view of the road at a specific point.

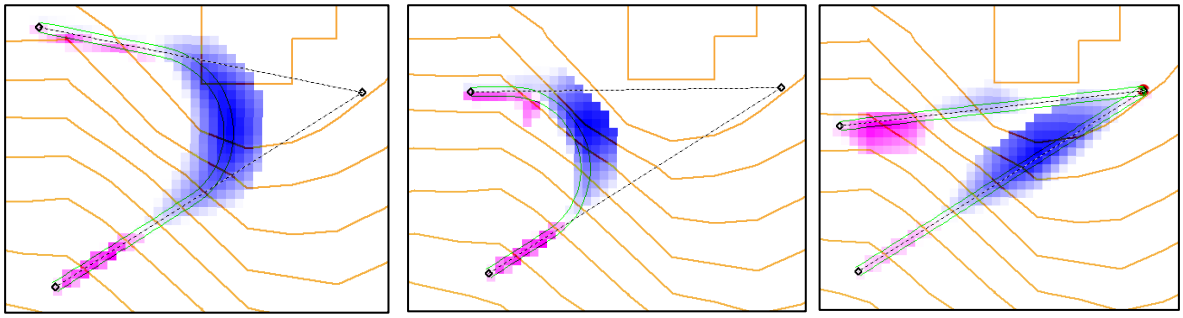
In the section view, it is possible to see the cross section marked of the terrain in a specific section. The road and cut slope is marked with a black line, while the green area indicates the terrain. The cross section corresponds to the position of the cursor on the road on the map and in the profile view. When moving the cursor across the road on the map, the section view and profile view update accordingly. Likewise, when moving the mouse cursor across the profile view, the section view and road pointer is updated accordingly.



An example of how the profile view, section view and pointer on the map is synchronized. When moving the cursor in one window, the cursor follows the path in the other windows.

2.17.3 Road Curvatures

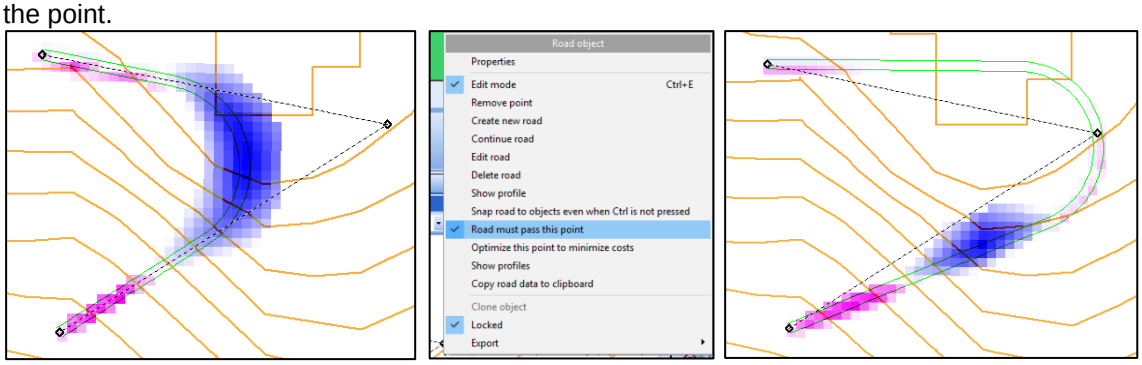
In the road object properties, the allowed curvature threshold can be specified. When moving the cursor to explore how the road should proceed, the bend will be drawn automatically to meet the curvature threshold.



1 2 3

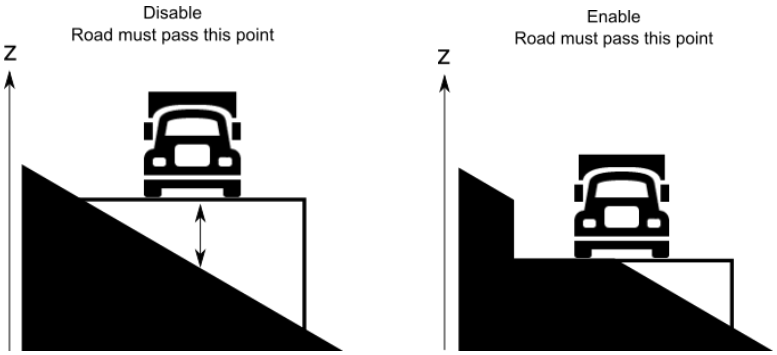
(1) Turns in the road are automatically drawn ensuring the allowed curvature threshold is met. (2) Digs and fills are simultaneously updated to account for, e.g., more vertical cutting. (3) If the bend in the road is too sharp, a warning appears in the information window and the curve will not be drawn. The point will also be colored red. In general, avoid exceeding road curvature thresholds by using as few points with as much distance between them as possible.

If the road has to go through a certain point, this can be activated by right-clicking the point and selecting **Road must pass thorugh this point**. Alternatively, hold down the CTRL key while adding the point.



1 2 3

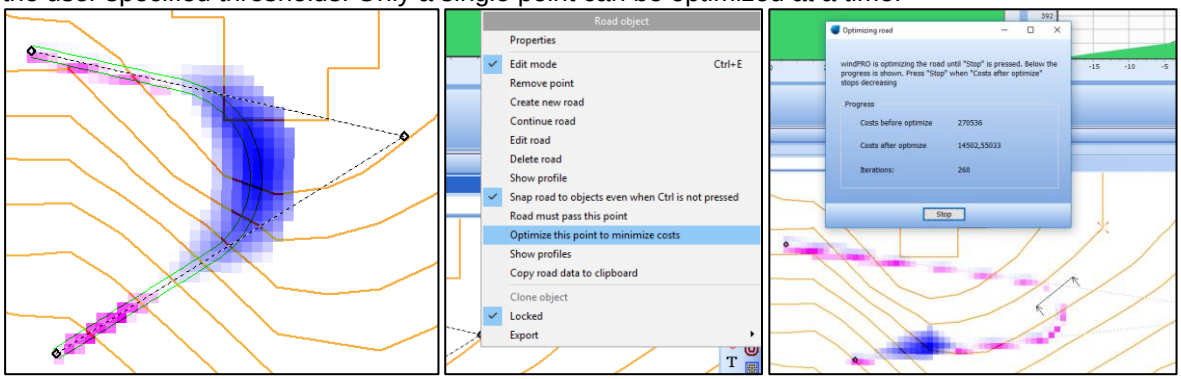
*(1) By default, the road curve will be drawn between two end points and the middle point will act as handle for the curve. (2) If the road must pass a certain point, it can be specified by right-clicking the point and selecting **Road must pass this point**. (3) The road will now pass through this point. This also locks the z-value of the road to the surface.*



*When enabling **Road must pass this point** the z-value of the road is also locked to the z-value of the terrain surface. This way it is possible to influence the profile of the road.*

2.17.4 Optimize road subsection

The road construction tool can optimize part of the road to minimize the costs. Like the OPTIMIZE module, windPRO experiments with different positions of the point to find a better layout, adhering to the user specified thresholds. Only a single point can be optimized at a time.



*To optimize the position of a single point, right click it and select **Optimize this point to minimize costs**. windPRO will then test different layouts and minimize the costs of that subsection of the road.*

2.18 BASIS - Cost functions

From windPRO 3.5 it is possible to define cost functions for multiple renewable energy technologies, including onshore and offshore wind turbine plants, solar PV plants and batteries. These cost functions are defined centrally and can be used multiple places to calculate cost of energy. From windPRO 3.6 this includes PARK, HYBRID and OPTIMIZE.

One major benefit with the cost functions is the use in optimizations, where the costs of a plant vary with the plant designs. As such, optimized plant designs are not limited to maximizing AEP but maximizing Net Present Value (NPV) or minimizing LCOE. This naturally includes a calculation of the internal turbine distances in a windfarm for approximate calculation of internal grid and road costs.

In general, the cost functions in windPRO are subdivided into four cost categories:

Development Expenditures (DEVEX): DEVEX is typically a percentage of CAPEX and relates to all activities occurring before the wind farm is constructed, like planning and permitting.

For discounting reasons, the start year for DEVEX is by default one year before CAPEX.

Capital Expenditures (CAPEX): CAPEX the main cost category, which includes turbine foundations, cranes etc.

The cost functions do not consider taxes and loans. Therefore, CAPEX and AEP start in the same year. This assumes the investment is paid upfront. This assumption can be modified in HYBRID which can handle loans.

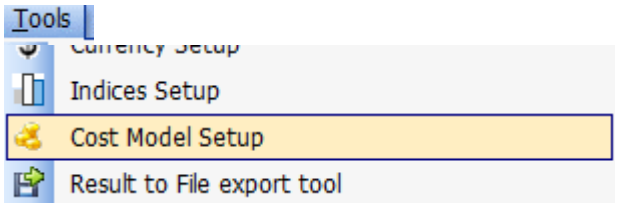
Operating Expenses (OPEX). These are the recurring expenses happening every year like maintenance, taxes and rent.

OPEX will begin one year after CAPEX. This can be adjusted in HYBRID.

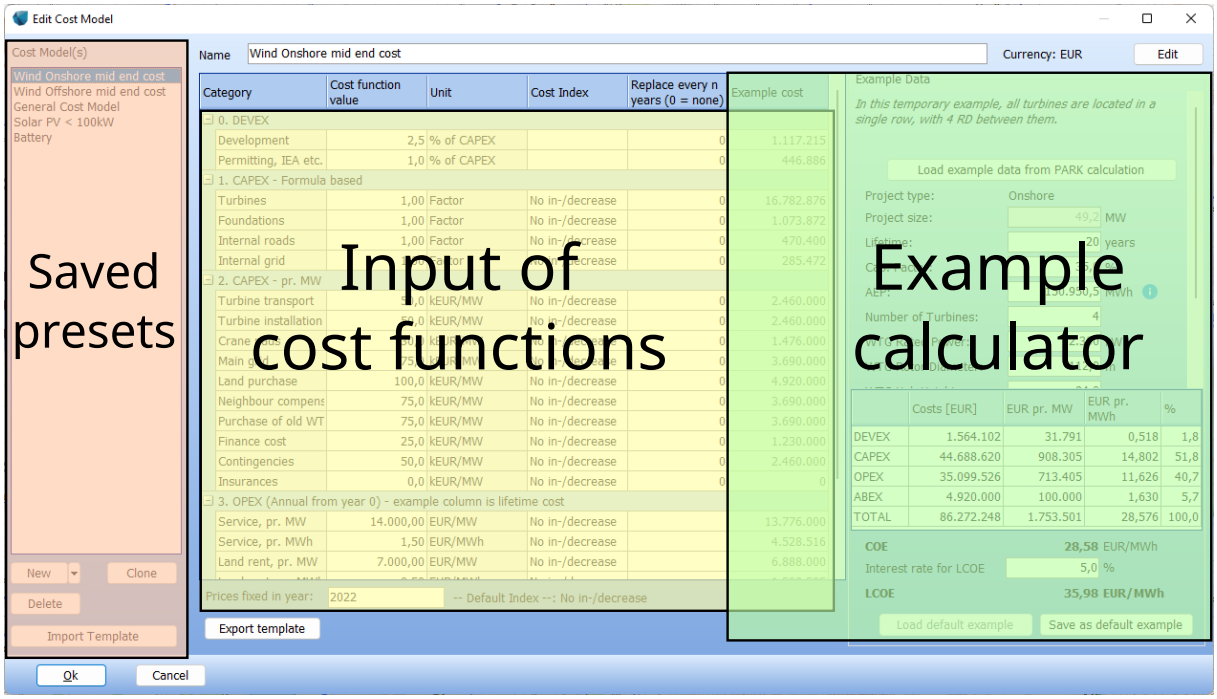
Abandonment Expenditures (ABEX): is the cost of dismantling the plant after end of operation. This expenditure is placed one year after the last operation year. This can also be changed in the HYBRID.

2.18.1 Cost Model Setup

The Cost Model Setup can be accessed from the Tools menu:

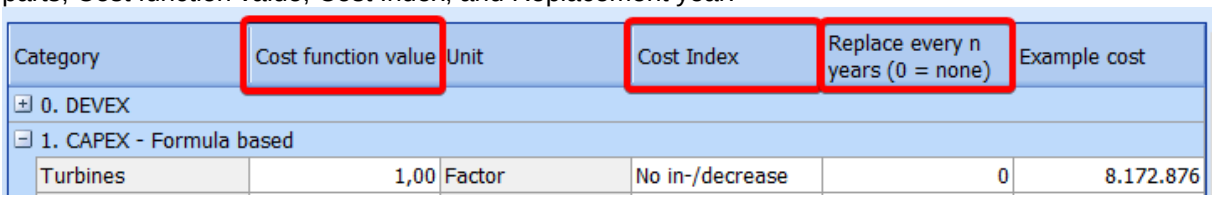


The window consists of three areas:



In the left-hand side, it is possible to store multiple cost models. This is useful when wanting to simulate different cost scenarios in different regions and for different technologies.

The center of the window is where the actual cost functions are defined. Each cost consists of three parts, Cost function value, Cost Index, and Replacement year:



Category	Cost function value	Unit	Cost Index	Replace every n years (0 = none)	Example cost
⊞ 0. DEVEX					
⊟ 1. CAPEX - Formula based					
Turbines	1,00	Factor	No in-/decrease	0	8.172.876

Cost function value: This is the most important parameter as it will be passed into the cost calculation and scaled to the plant size. For CAPEX, the costs are both defined per MW and by formulas. The cost of a WTG is therefore calculated based on a formula considering the individual turbine's hub height, rotor size and power (see section 2.18.2 Cost function formulas), while the cost of Turbine transport is simply a cost per MW.

Cost index: Defines how costs will change in the future

Replace every n years: Defines when a cost component needs replacement after a certain amount of years in operation. Unfortunately, it is not possible to specify replacement of e.g., gearbox, blades etc. so this is mostly useful for Solar PV costs.

Example Cost: This is NOT used in any PARK, HYBRID or OPTIMIZE calculation. It simply displays the estimated absolute costs under some temporary assumptions exemplified in the right-side panel.

In the right-side panel, it is possible to specify characteristics of an example plant. The purpose is to give an idea about how the cost functions will manifest themselves in absolute terms. The example data are temporary and are not used in any calculations outside of the Cost Model Setup. It is possible to calibrate the cost function values using the example cost, see section 2.18.1.2 Calibration of cost functions.

2.18.1.1 Adding a new cost model

windPRO comes with a list of cost models predefined and it is possible to add new cost models for the following technologies:

Wind Onshore: This includes typical project costs for turbines, foundations, transport, internal grid etc. Additionally, it also includes onshore specific costs such as roads, crane pads, neighbor compensation etc.

Wind Offshore: This also includes typical costs and some specific offshore costs like offshore main cable, sea rights fees, offshore sub-station etc.

PV projects: This covers solar panels, inverters, grid, installation, trackers etc.

Battery: Scales with the size of the storage size, charge and discharge rate, installation etc.

General: A simple cost model, only applicable in the HYBRID module to model any type of technology which is neither wind, solar or batteries.

To add a new cost model setup for one of the above technologies, click the New button I the lower left corner:

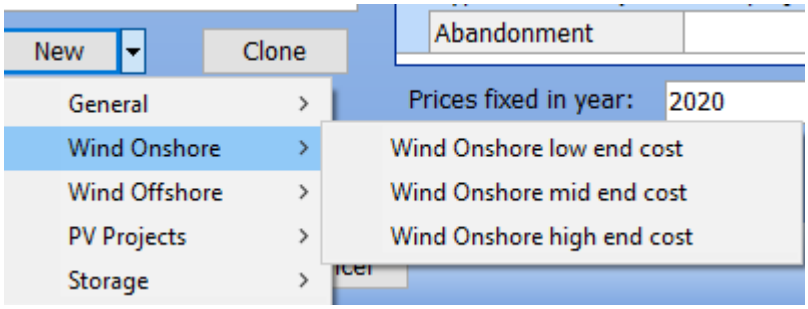


Figure 1 Wind cost functions subdivided in on- and offshore, low-mid-high.

For wind and PV there are different subsets of default cost values. For wind onshore as well as offshore there are low-, mid- and high-end cost functions. For PV there are subsets based on plant sizes and whether tracking is included or not. For “General” (e.g., a Hydro plant) and storage (Battery), there is only one cost function template.

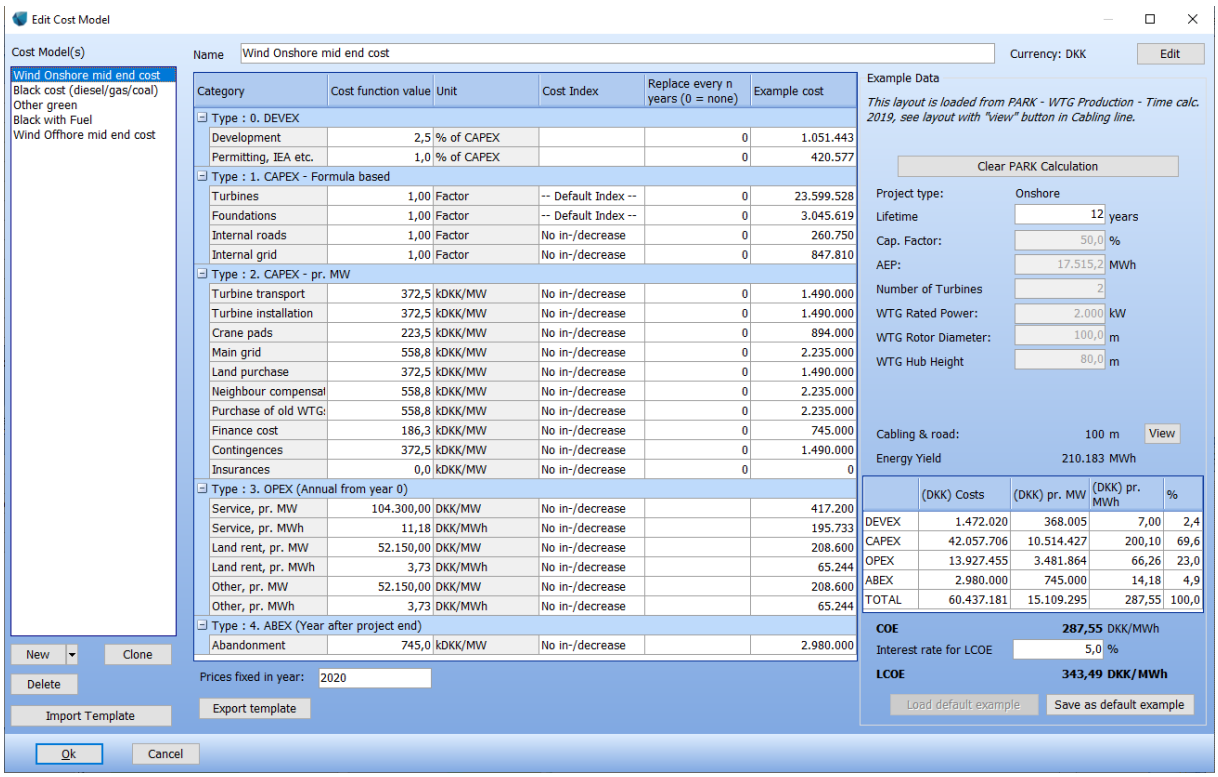


Figure 2 Example of a cost function for wind onshore mid end cost.

It is important to understand that when PARK, OPTIMIZE or HYBRID uses the specified cost model, the final calculation will be based on the values defined in the “Cost function value” column, and NOT on the absolute costs shown in the “Example cost” column. The “Example cost” column only shows the estimated costs for an example plant defined on the right- hand side.

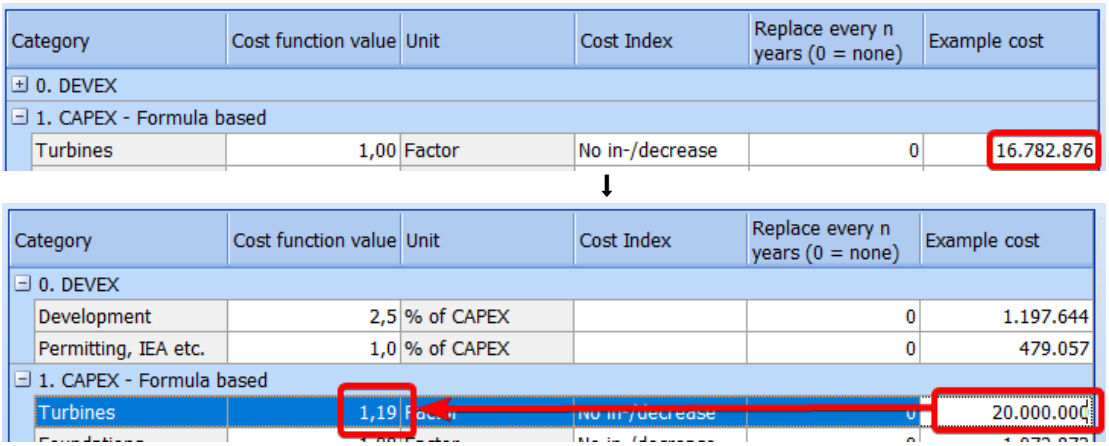
The “Cost function value” is used to find the costs for a specific plant in a specific calculation.

The example data is also context specific. So, if the Cost Model Setup window was opened from inside e.g., a PARK calculation, then the example data will reflect the PARK setup as closely as possible. The purpose is to give an indication of the absolute costs for a given set of cost function values.

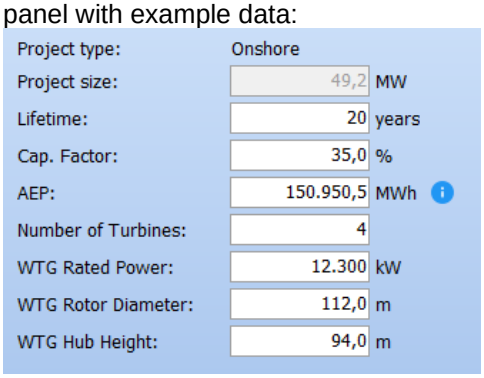
For non-formula-based costs, there are specific cost values, typically EUR/kW or kEUR/MW. Notice that the currency can be changed to any other currency See section 2.18.1.5 Currency.

2.18.1.2 Calibration of cost functions

In case the absolute costs of an expenditure are known in advance, it is possible to calibrate the cost function value. Simply enter the known cost in the Example cost column. Then the Cost function values will be updated to reflect this price, and the cost function can be saved/exported and used for new projects and calculations.



Bear in mind, that the values in the “Example cost” column reflect the input data in the right-hand side panel with example data:



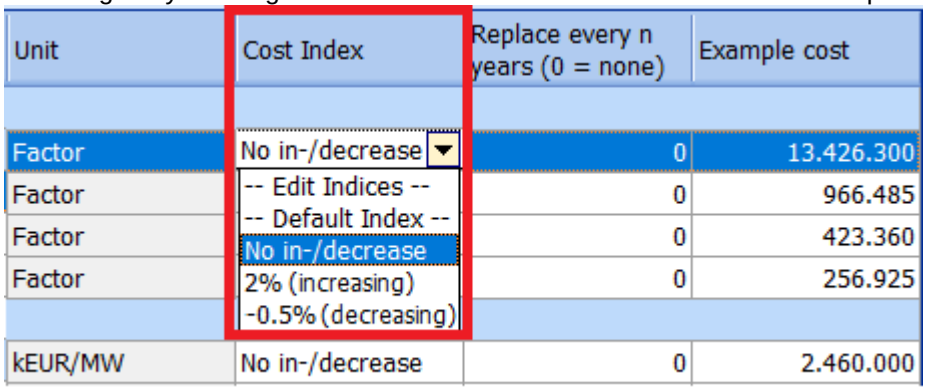
This way the “Cost function value” is appropriately calibrated to e.g., the number of turbines in the park.

For instance, if the park consists of 4 turbines and the “Example cost” value for “Turbines” is manually stated to be 20M €, that means 1 turbine with the characteristics defined in the right-side panel will cost 20/4= 5M €.

2.18.1.3 Price year for fixed prices

The prices entered in the Cost Model Setup are always specific to a specific year:

When using the Cost model in a PARK,OPTIMIZE or HYBRID calculation the costs will be projected to the investment start year of that calculation. To make such projection, the yearly cost increase or decrease must be declared. By default, windPRO assumes no changes in cost over time, but this can be changed by defining cost indices in the Cost Index column for each expenditure:



windPRO has three predefined indices:

No in-/decrease: This means the costs defined in the Cost Model Setup will be the same in any investment start year.

2% (increasing): This means every year the cost will increase by 2%.

For CAPEX the costs will increase 2% from the “Prices fixed in year” to the investment start year (as defined in PARK or HYBRID).

For OPEX, the cost increases 2% every year until the project lifetime as defined in PARK, HYBRID or OPTIMIZE.

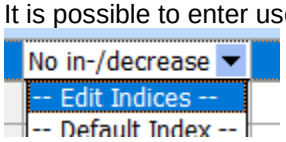
An example could be turbines becoming more expensive year by year.

Notice, that the index correction only applies for future changes in cost. If the investment year lies earlier than the specified “prices fixed in year”, then the costs will not be index corrected backwards.

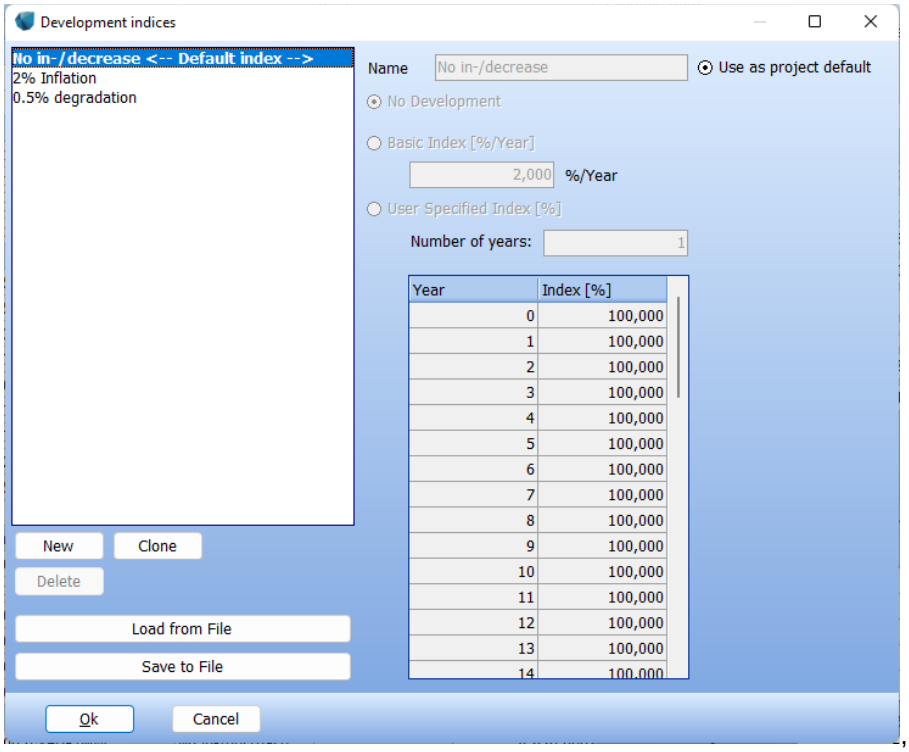
-0.5% (decreasing): This means every year the costs will decrease with 0.5%

An example could be storage, where a common assumption is that the costs will be halved from 2020 to 2030. To incorporate this, a cost index with annual decrease of 7% can be used and the price will be halved over 10 years. This makes it possible to simulate storage establishment for different years where the cost automatically updates based on the start year. For most components it is recommended to just use inflation or “No in-/decrease” in order not to make the calculation very sensitive to the year of establishment.

It is possible to enter user-defined cost indices by clicking “—Edit indices –” in the dropdown menu:



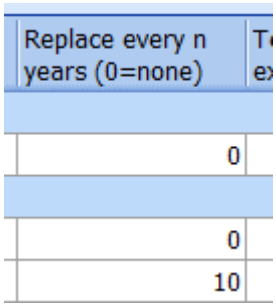
This opens the Development Indices window:



Here it is possible to add new indices and specify how the costs will change every year or in certain years. For instance, the cost of a Service contract may stay constant for the first 10 years and then be renewed at a different cost from years 10 to 20.

2.18.1.4 Replacements

It is possible to enter replacement frequencies for each expenditure:

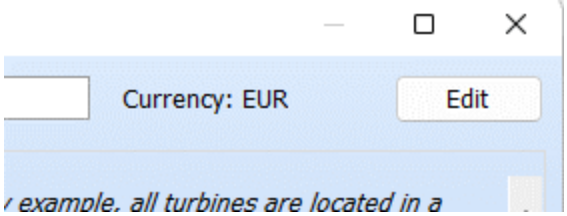


A typical example could be inverters for solar-PV projects. These may be assumed to have shorter lifetime than the PV panels. If the lifetime is set to 20 years for the project, and the inverter replacement is set to 10 years, then the cost of inverters will be included twice. Scrap value is not included in the calculation.

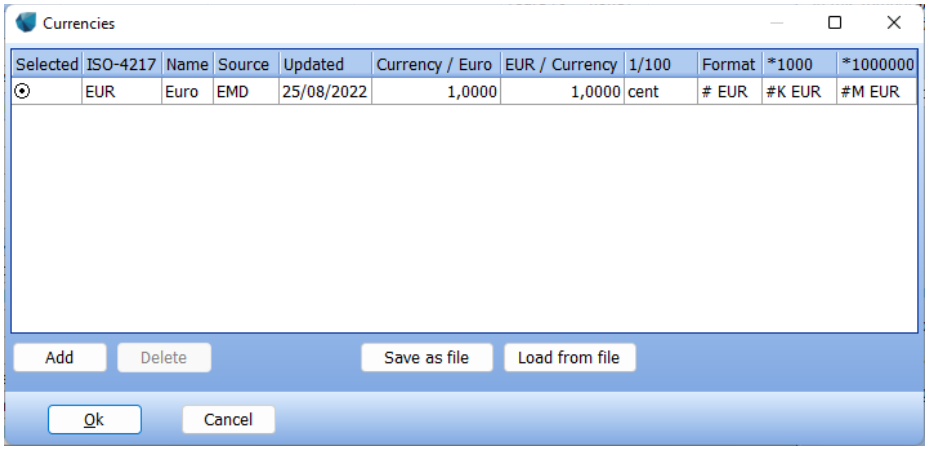
If a cost index for the specific expenditure has been added, then that will also be used for calculating the projected costs in the years of replacement.

2.18.1.5 Currency

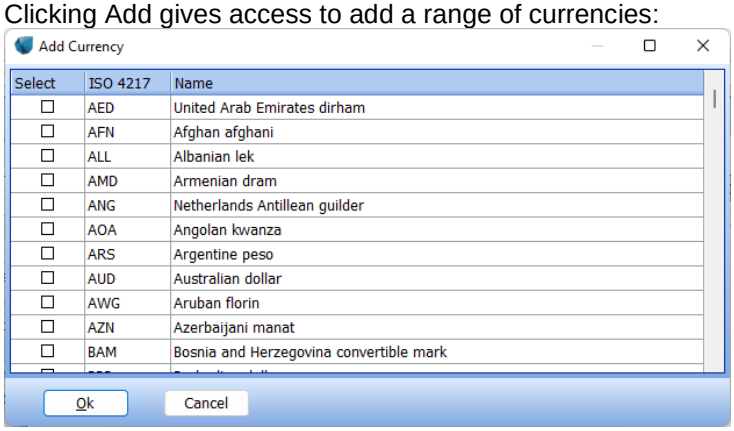
By default, the cost calculator uses Euro as the background currency. However the displayed currency can be changed by clicking the Edit button:



This opens the currency list where it is possible to add, delete and edit currencies:



Clicking Add gives access to add a range of currencies:



Changing the currency will automatically update the costs per MW.

2.18.1.6 COE and LCOE calculations

Cost Of Energy (COE) is all lifetime costs (optionally, index corrected) divided by the lifetime production.

Levelized Cost Of Energy (LCOE) is the annual costs and productions discounted with a specified interest rate. The interest rate is defined in the calculation setup in PARK, HYBRID and OPTIMIZE.

2.18.2 Cost function formulas

The values are based on a comprehensive study in Spring 2020 by Per Nielsen, EMD, where several data sources from the likes of NREL, Danish Energy Agency, etc., in combination with internal data for recently-built projects in Denmark and by Internet searches. In the Summer 2022 a few updates were included, reflecting the cost increases seen partly based on higher inflation in 2022, partly based on high raw material cost increases. While costs differ quite significantly depending on manufacturer/quality, region, distance to manufacturer/harbor etc., the costs only can be seen as good initial design assumptions. More detailed information must be gathered when the project moves from the initial assessment phase to the final decision phase. The cost functions can be calibrated with known data from similar project styles/locations, see section 2.18.1.2 Calibration of cost functions.

2.18.2.1 Wind

The formulas are based on an analysis of many turbines and literature studies to find which parameters drive the costs.

Abbreviations for wind plants used in cost formulas:

- kW – Turbine power (kW)
- MW – project power (MW)
- RD – Rotor diameter (m)
- RA – Rotor Area (m²)
- HH – Hub Height (m)
- SP – Specific power (W/m²)
- IA – Inter Array distance (m)
- No – Number of turbines
- WD – Water Depth
- CD – Coast Distance

For wind plants the following formulas are established with year 2020 values and 2022 updates shown:

Turbines
A*SP+B+(C*HH*RA+D)/kW [k€/MW]
Where:
A = -0.5 [(k€/MW) / (W/m²)]
B = 750 [k€/MW] (2022, revised to 925, see check below)
C = 0,53 [€/m³]
D = 5500 [€]

The cost increase for wind turbines from 2020 to 2022 is very high (approx. 25%), mainly due to raw material cost developments, but also the higher inflation. Below is shown a cost function check for 2020 values and for 2022 values, based on list prices for turbines for sale in Denmark from a major manufacturer who represents a large part of the global market.

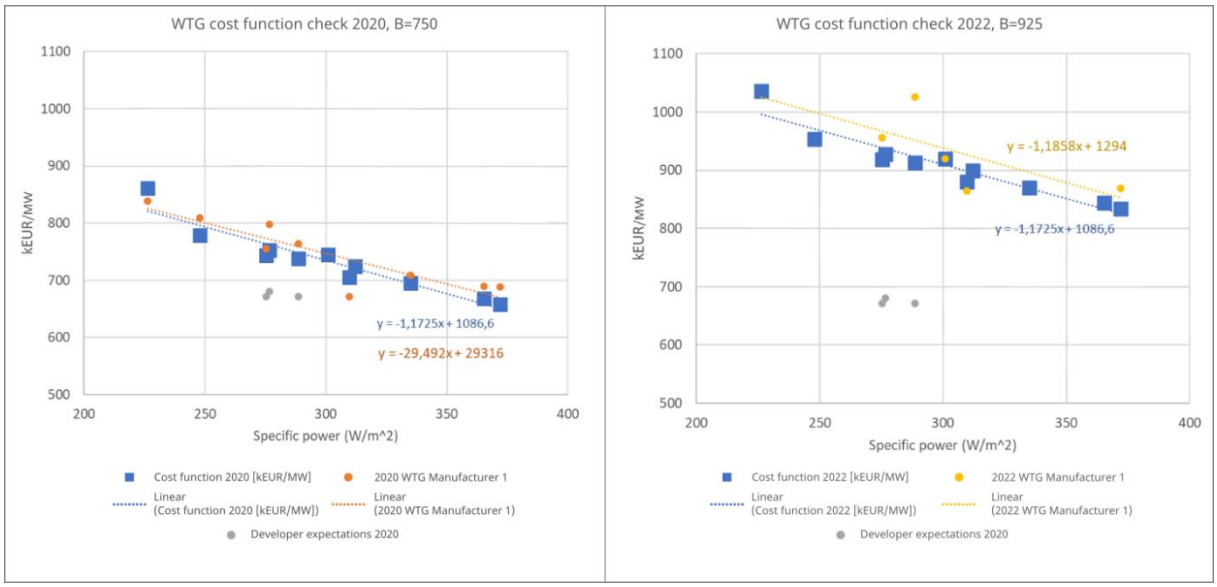


Figure 3 Cost function check for turbines, left 2020, right 2022

As seen above, the 2022 costs follow a slope similar to the 2020 costs, but with an offset from 750 to 925, a 23% increase. Included in the charts are the project developer expectations from 2020 (see https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_el_and_dh.pdf), which are lower than the list prices. The real costs largely depend on the specific purchase situation, whether an order can be fitted into the production plan and the purchase volume. The cost function calculation result is purposely a little lower than list prices as the realized prices often are lower than list prices.

In the graph above the data are typical for low hub height variants due to height restrictions on the Danish market. The formula-based cost function values increase ~2% per 10m hub height increase. Depending on the specific turbine construction, up to 5% increase per 10m has been observed.

Foundations onshore
A*(RA*HH)^B [k€]
Where:
A = 0.0172 [k€/MW/m³]
B = 0.703

Internal roads
IA * A [€]
Where:
A = 350 [€/m]

Internal grid onshore
IA * A + B [€]
Where:
A = 138 [€/m]
B = 100.000 [€]

Foundations offshore
A*WD+B [k€/MW]
Where:
A = 8 [(k€/MW)/m]
B = 30 [k€/MW]

Offshore main cable
A * CD [k€/MW]
Where:
A = 2,8 [k€/MW/km]

Internal grid offshore
IA * A [€]
Where:
A= 500 [€/m]

These formulas are expected to work for modern (since year 2020) wind turbines with a rating of approximately 2.5 MW and higher. For smaller turbines, higher costs must be expected.
Note the cost calculator calculates the inter array distance, as the shortest connection between the WTGs and uses this for cable and road cost estimates, which may not always be realistic.

An example of a specific cost at present that is going to be revised in future is offshore foundation installation. It is known that the installation costs do not double by doubling the WTG size (as will be calculated using a fixed cost per MW), it is more like a factor 0.6. Such experience feedback will be incorporated in future updates.

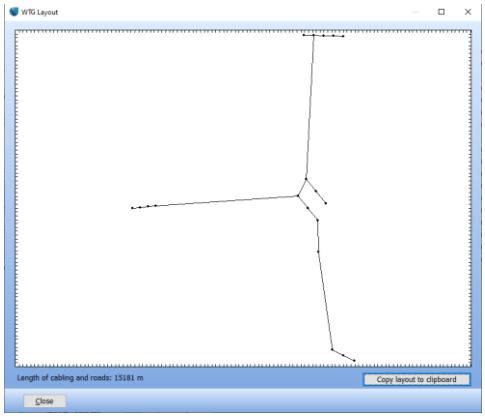


Figure 4 Automatic inter array distance calculation for a PARK calculation.

2.18.2.2 Solar PV

For Solar-PV plants the cost functions are all specific costs (€/Wp). Data for 2020 and 2022 revisions are shown below.

2020 price level €/Wdc	**Solar PV**			
	Small , 2.5-10 kW	Medium, 10-100 kW	Large > 100 kW	Large, Tracking
DEVEX	<sæt til 1% af Capex, vi har ikek rigtig noget p			
CAPEX				
Solar panels	0,70	0,40	0,23	0,23
Inverters	0,25	0,15	0,05	0,05
Sub structures			0,02	0,02
Grid internal	0,02	0,01	0,01	0,01
Grid, external			0,16	0,16
Installation	0,35	0,30	0,19	0,19
Land purchace			0,00	0,00
Other/contingency	0,50	0,12	0,11	0,11
Tracker costs				0,07
Total DEVEX+CAPEX:	**1,82**	**0,98**	**0,76**	**0,84**
OPEX Per year from year 1 to end				
O&M, pr. kW	13,4	10,9	5,0	5,5
Land rent, pr. kW	0,0	0,0	2,3	2,3

2022 price level €/Wdc	**Solar PV**			
	Small , 2.5-10 kW	Medium, 10-100 kW	Large > 100 kW	Large, Tracking
DEVEX	<sæt til 1% af Capex, vi har ikek rigtig noget p			
CAPEX				
Solar panels	0,70	0,45	0,30	0,30
Inverters	0,25	0,15	0,05	0,05
Sub structures			0,02	0,02
Grid internal	0,02	0,01	0,01	0,01
Grid, external			0,13	0,13
Installation	0,35	0,25	0,14	0,15
Land purchace			0,00	0,00
Other/contingency	0,50	0,12	0,11	0,11
Tracker costs				0,07
Total DEVEX+CAPEX:	**1,82**	**0,98**	**0,76**	**0,84**
OPEX Per year from year 1 to end				
O&M, pr. kW	13,4	10,9	5,0	5,5
Land rent, pr. kW	0,0	0,0	2,3	2,3

Figure 5 Solar-PV cost functions 2020 left with revisions 2022 right.

The 2022 revisions have increased the solar panel costs. Experience shows that the cost of 0.23 EUR/Wp used in the 2020 dataset were too low (based on Danish Technology catalogue, https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_el_and_dh.pdf). Our expectations for 2022 is 0.3 EUR/Wp for larger installations. But while the total costs for a PV project were validated and found representative, some of the other cost elements have been lowered. Thereby the 2020 and 2022 costs remain the same for the full plant costs.

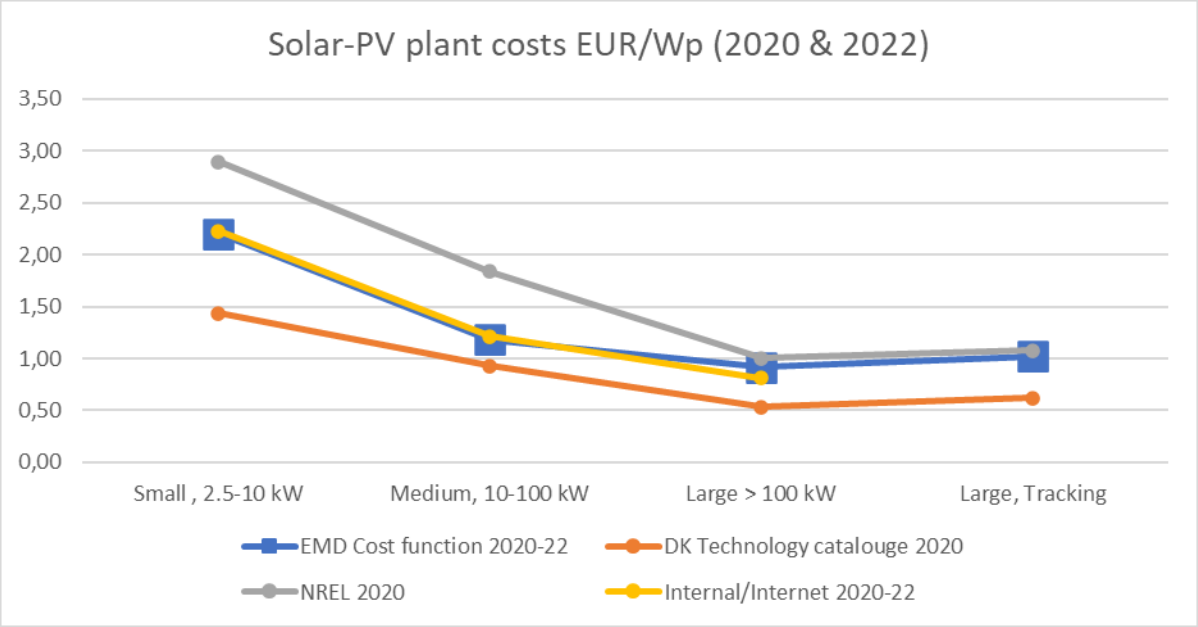


Figure 6 Solar-PV plant costs

The cost function output from windPRO is located between the Danish technology Catalogue and NREL. One cost component that can vary much by site is the AC connection costs. If grid expansion is needed, these costs can be high. Similar land costs are not included by default, this can also add up if good farming land is needed.

2.18.2.3 Other technologies

Apart from the formula-based cost functions, a number of costs are simply per MW or MWh or a percentage.

Name: General Cost Model — Currency: EUR — Edit

Category	Cost function value	Unit	Cost Index	Replace every n years (0=none)	Temporary example plant cost
0. DEVEX					
Development Expen	0,00	% of CAPEX		0	0
1. CAPEX - pr. kW					
Capital Expenditure	500.000,00	EUR/MW	No in-/decrease	0	500.000
2. OPEX (Annual from year 0)					
Operation Pr MW	10.000,00	EUR/MW	No in-/decrease		200.000
Operation Pr MWh	0,00	EUR/MWh	No in-/decrease		0
Fuel cost Pr MWh	100,00	EUR/MWh	No in-/decrease		3.506.400
3. ABEX (Year after project end)					
Abandonment	0,00	EUR/MW	No in-/decrease		0

Prices fixed in year: 2021 -- Default Index --: No in-/decrease

Temporary example plant cost

Project Size:	1.000	kW
Capacity Factor:	20,0	%
AEP:	1.753,2	MWh
Lifetime:	20	years
Energy Yield:	35.064	MWh

	Costs [EUR]	EUR pr. MW	EUR pr. MWh	%
DEVEX	0	0	0,00	0,0
CAPEX	500.000	500.000	14,26	11,9
OPEX	3.706.400	3.706.400	105,70	88,1
ABEX	0	0	0,00	0,0
TOTAL	4.206.400	4.206.400	119,96	100,0

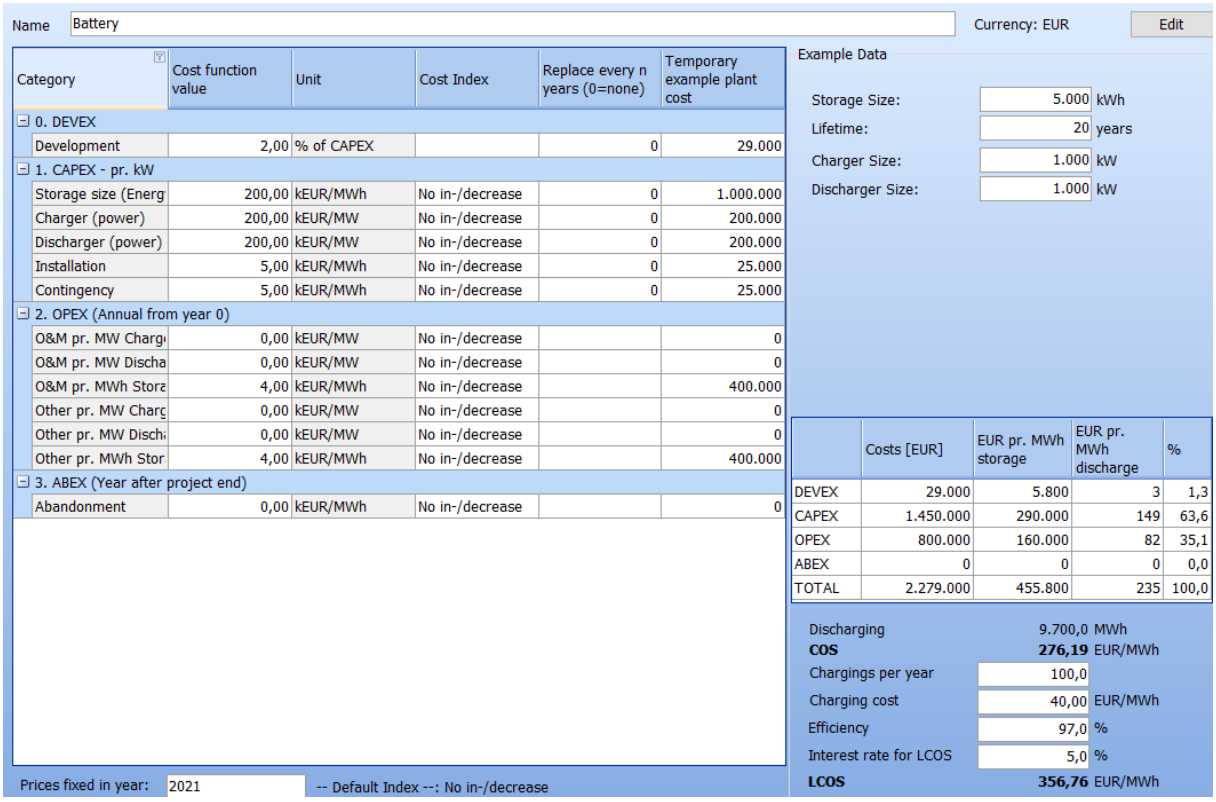
COE **119,96** EUR/MWh

Interest rate for LCOE 5,0 %

LCOE **127,50 EUR/MWh**

Figure 7 General cost model, for e.g., a fossil-powered back-up plant.

The general cost model can basically be used for all production technologies with few simple input data. CAPEX, is one line (Turnkey-costs). OPEX is one line per MW, one line per MWh and an extra line with Fuel costs, to make it easier to distinguish between maintenance and fuel costs. The maintenance and fuel costs, both per MWh is so far treated similar in HYBRID calculations where the cost function is used.



Name: Battery — Currency: EUR — Edit

Category	Cost function value	Unit	Cost Index	Replace every n years (0=none)	Temporary example plant cost
0. DEVEX					
Development	2,00	% of CAPEX		0	29.000
1. CAPEX - pr. kW					
Storage size (Energ	200,00	kEUR/MWh	No in-/decrease	0	1.000.000
Charger (power)	200,00	kEUR/MW	No in-/decrease	0	200.000
Discharger (power)	200,00	kEUR/MW	No in-/decrease	0	200.000
Installation	5,00	kEUR/MWh	No in-/decrease	0	25.000
Contingency	5,00	kEUR/MWh	No in-/decrease	0	25.000
2. OPEX (Annual from year 0)					
O&M pr. MW Charg	0,00	kEUR/MW	No in-/decrease		0
O&M pr. MW Discha	0,00	kEUR/MW	No in-/decrease		0
O&M pr. MWh Stora	4,00	kEUR/MWh	No in-/decrease		400.000
Other pr. MW Charg	0,00	kEUR/MW	No in-/decrease		0
Other pr. MW Disch	0,00	kEUR/MW	No in-/decrease		0
Other pr. MWh Stor	4,00	kEUR/MWh	No in-/decrease		400.000
3. ABEX (Year after project end)					
Abandonment	0,00	kEUR/MWh	No in-/decrease		0

Prices fixed in year: 2021 -- Default Index --: No in-/decrease

Example Data

Storage Size:	5.000	kWh
Lifetime:	20	years
Charger Size:	1.000	kW
Discharger Size:	1.000	kW

	Costs [EUR]	EUR pr. MWh storage	EUR pr. MWh discharge	%
DEVEX	29.000	5.800	3	1,3
CAPEX	1.450.000	290.000	149	63,6
OPEX	800.000	160.000	82	35,1
ABEX	0	0	0	0,0
TOTAL	2.279.000	455.800	235	100,0

Discharging	9.700,0	MWh
COS	**276,19**	EUR/MWh
Chargings per year	100,0	
Charging cost	40,00	EUR/MWh
Efficiency	97,0	%
Interest rate for LCOS	5,0	%
LCOS	**356,76**	EUR/MWh

Figure 8 Storage cost structure and defaults.

The storage cost is composed differently from the production unit costs, as the main “size” here not is MW, but MWh. The key figures shown to the right in the above image are the cost per MWh storage and cost per MWh discharge. To calculate the discharge, the discharge amount per year must be known.

In the lower right corner, the number of charges per year can be entered. The default is set to 100 charges per year. Thus, it is assumed that the storage delivers a full discharge roughly every 3rd day on average. Also, the charging costs impact the cost per M€Wh discharge. When the cost function is used from the HYBRID module the real calculation values from the simulation is used. This is also used for calculating LCOS (Levelized Costs Of Storage).

For Storage (Batteries) and Generic cost model (e.g., for a hydro plant), no revisions have been made from 2020 to 2022. The high inflation in 2022 makes it difficult to spot development trends at present.