Welcome!

Webinar #11: The Wind Turbine Feature in THERMOFLEX
13 September 2017

Agenda:

* Introduction

* The Wind Farm Component

* TD Mode / OD Mode: inputs, calculation and outputs

* Annual Output Estimate

* Examples

* Q & A Session

Presenter: IGNACIO MARTIN (SPAIN)
Support: Meritt Elmasri (U.S. HQ)

Thermoflow Training and Support

- Standard Training

- On-Site Training course

- Advanced Workshop

- Webinars when new version is released

- Help, Tutorials, PPT, Videos

- Technical Support

→ Feature Awareness Webinars

Feature Awareness Webinars

1- Assemblies in TFX

2- Scripts in Thermoflow programs, GTP-GTM-TFX

3- Multi Point Design in GTP-GTM

4- Reciprocating Engines in TFX

5- TIME in GTM

6- Matching ST Perfromance in STP

7- Modeling Solar Systems in TFX

8- Combining THERMOFLEX & Application-Specific Programs

9- Methods & Methodology in GT PRO & STEAM PRO

10- Supplementary Firing & Control Loops in GT PRO & GT MASTER

11- The Wind Turbine Feature in Thermoflex

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Wind Farm Component in TFX

- Available since Version 26 (2016)
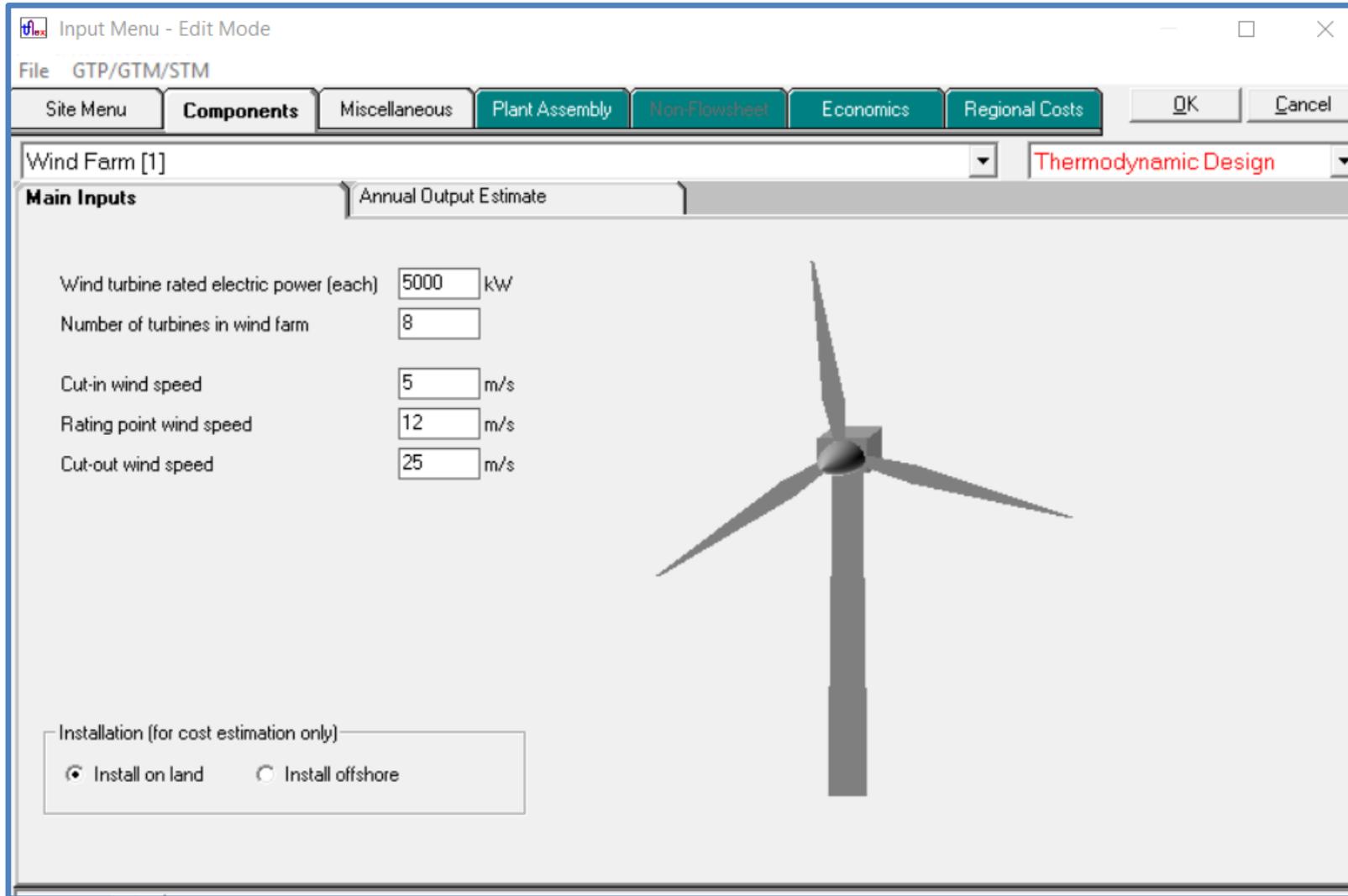- Can represent 1 Turbine or a Wind Farm
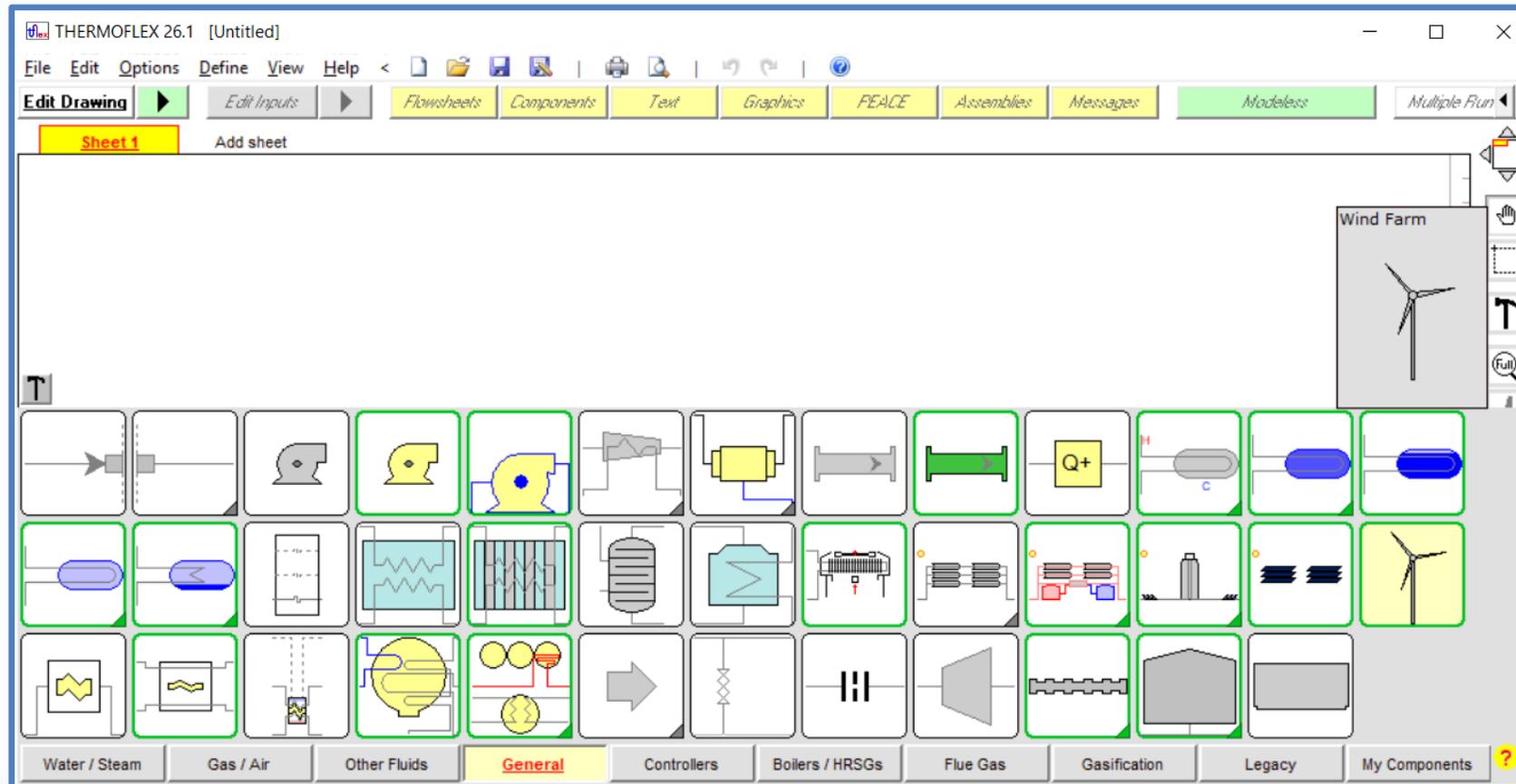
TD Inputs

Inputs:

- Rated Power of 1 Turbine (10 kW to 10 MW)
- Number of Turbines
- Wind Speed: rating point, cut-in & cut-out
- Installation: On Shore / Off Shore
- Annual Output Estimate(if enabled):
    - User Defined Wind Speed at Hub height
    - Data from Wind Resource File

TD Inputs

TD Inputs

TD Calculations

From internal method:

- Curve Efficiency – Turbine size (developed from commercial models data)
  *maximum blading efficiency is the **Bett's limit of 59.3%***

- Power Curve: Power to wind speed
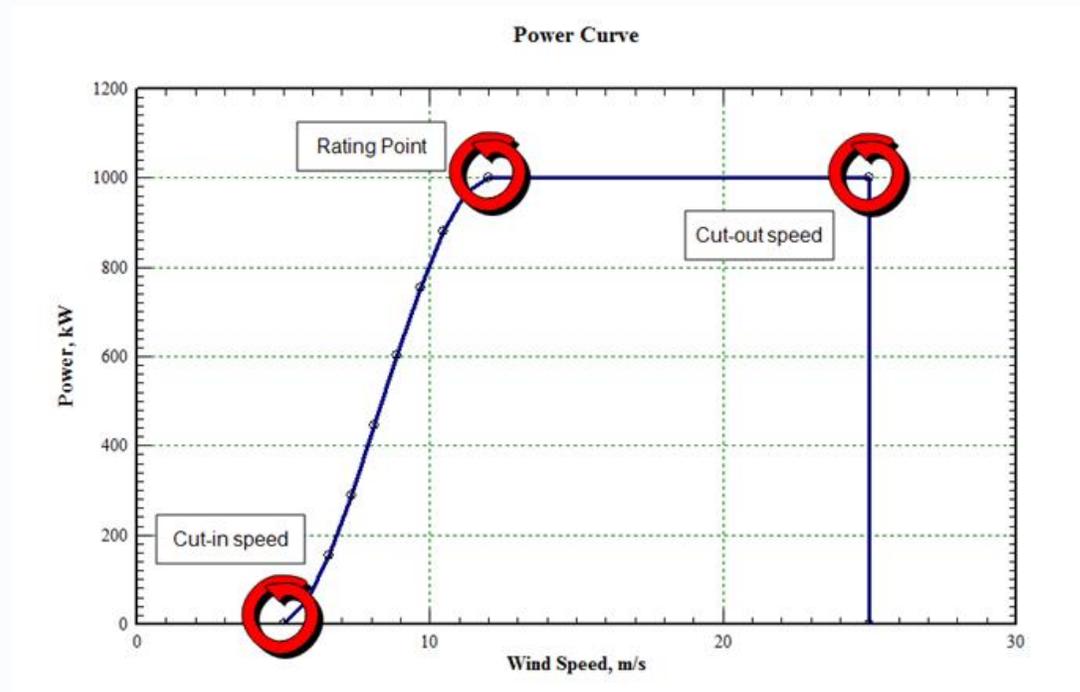
TD Outputs

Outputs:

- Rotor Diameter & Hub Height (function of rated Power)
- Overall Electric Efficiency
- Land Area
- Cost:
    - On Shore / Off Shore
    - Number of Turbines (1 to 20)
- Annual Output (if enabled):
    - User Defined Wind Speed at Hub height
    - Data from Wind Resource File

TD Outputs - Graphic

P[bar]   T[C]   H[kJ/kg]   M[t/h]
Wind Farm [1]
Mode: Engineering Design
Power output from wind farm = 40000 kW
Power output per wind turbine = 5000 kW
Rotor diamater = 142,4 m, Hub height = 142,4 m
Wind farm land area = 5.837.000 m^2, 583,7 hectare

Estimated annual output for wind farm = 350.400 MWhr
Using daily average wind speed at hub height = 12 m/s

TD Outputs - Performance

Performance		
Wind Farm [1]		
1. Performance Summary		
Power output from wind farm	40000	kW
Power output per wind turbine	5000	kW
Wind speed at turbine hub height	12	m/s
Wind power at turbine hub height	16784	kW
Overall electric efficiency	29,79	%
2. Estimated Annual Performance		
Estimated annual output for wind farm	350.400	MWhr
Annualized capacity (output / max possible output)	100	%
Annualized average wind speed at hub height	12	m/s
Number of hours per year that wind turbine operates	8760	hours
Percentage of year that wind turbine operates	100	%
Number of hours per year where wind is below cut-in speed	0	hours
Percentage of year where wind is below cut-in speed	0	%
Number of hours per year where wind is above cut-out speed	0	hours
Percentage of year where wind is above cut-out speed	0	%

TD Outputs - Specification

1. Wind farm layout		
Number of wind turbines	8	
Wind farm land area	584	hectare
Wind farm land area	5.837.000	m^2
Wind farm width	6.830	m
Wind farm length	854	m
Land aspect ratio	8	
Number of turbine rows	1	
Turbine spacing	854	m
2. Wind Turbine Specifications (per turbine)		
Rating electric power	5000	kW
Rating wind speed	12	m/s
Maximum efficiency (at velocity = 8,872 m/s)	44,34	%
Velocity at maximum efficiency	8,872	m/s
Rotor diameter	142,4	m
Hub height	142,4	m
Cut-in wind speed	5	m/s
Cut-out wind speed	25	m/s
Rating point air density	1,22	kg/m^3

| 3. Reference material, equipment and installation costs		
Equipment		
Wind turbine(s)	64.269.000	EUR
Electrical		
Electrical material cost	51.300	EUR
Electrical labor	4.530	hours
Electrical labor cost	171.050	EUR
Reference Electrical Cost subtotal	222.400	EUR
Mechanical		
Mechanical material cost	334.000	EUR
Mechanical labor	9.050	hours
Mechanical labor cost	334.000	EUR
Reference Mechanical Cost subtotal	668.000	EUR
Civil		
Foundation material cost	8.494.000	EUR
Excavation/backfill material and equipment cost	1.043.000	EUR
Civil labor	96.600	hours
Civil labor cost	3.130.000	EUR
Total reference civil cost subtotal	12.667.000	EUR
4. Cost Summary		
Total reference installed cost	**77.827.000**	**EUR**
Total installed cost adjustment factor	**1**	
Total estimated installed cost	**82.445.000**	**EUR**

TD Outputs – Plot and Power Curve
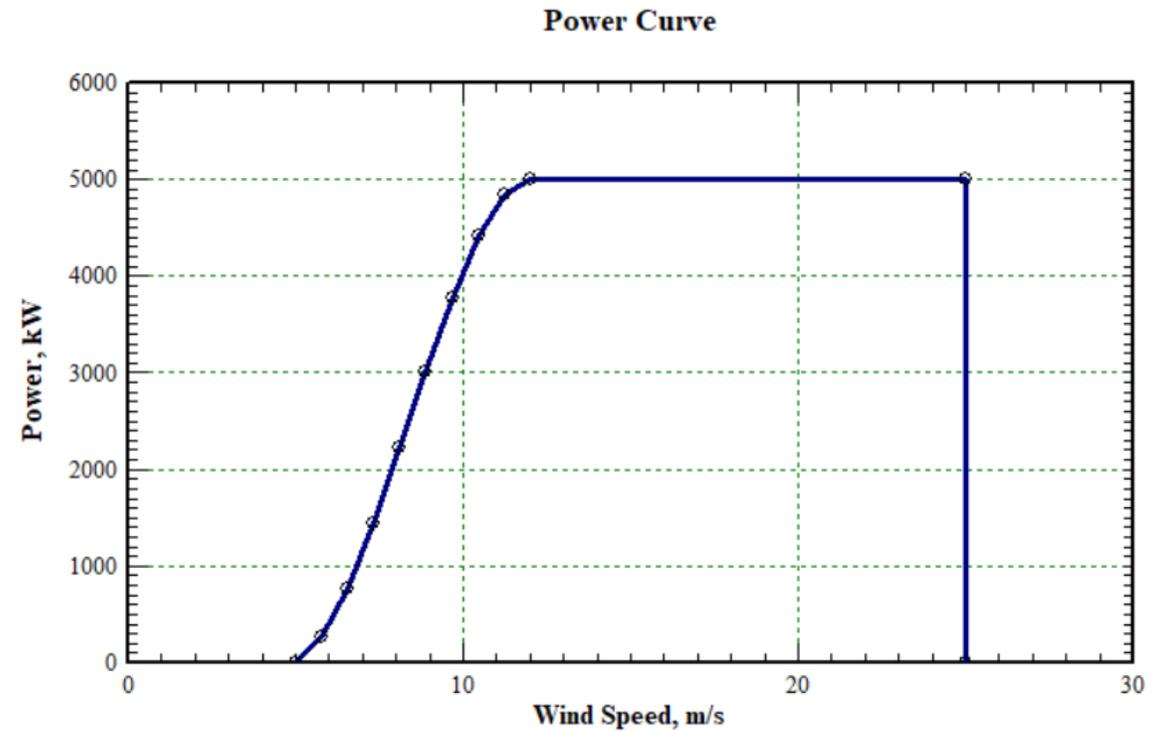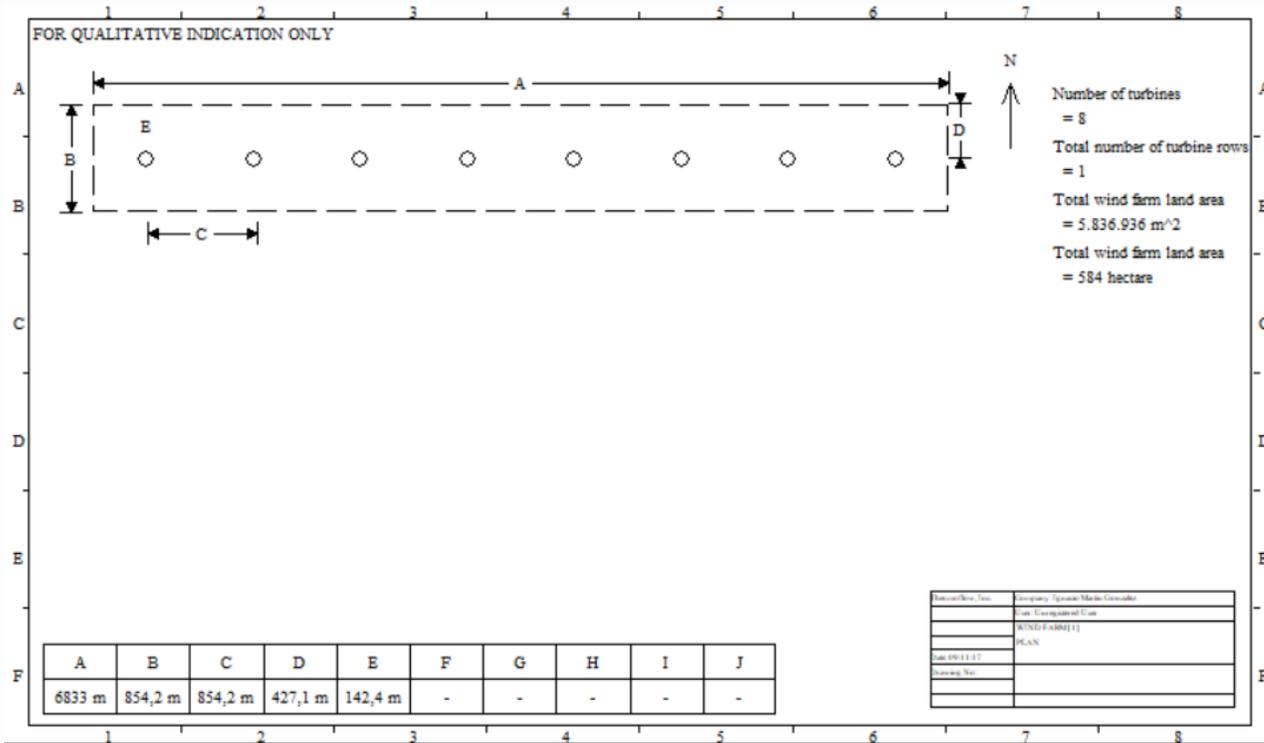
TD Automatic Rotor Diameter & Overall Eff vs. Power
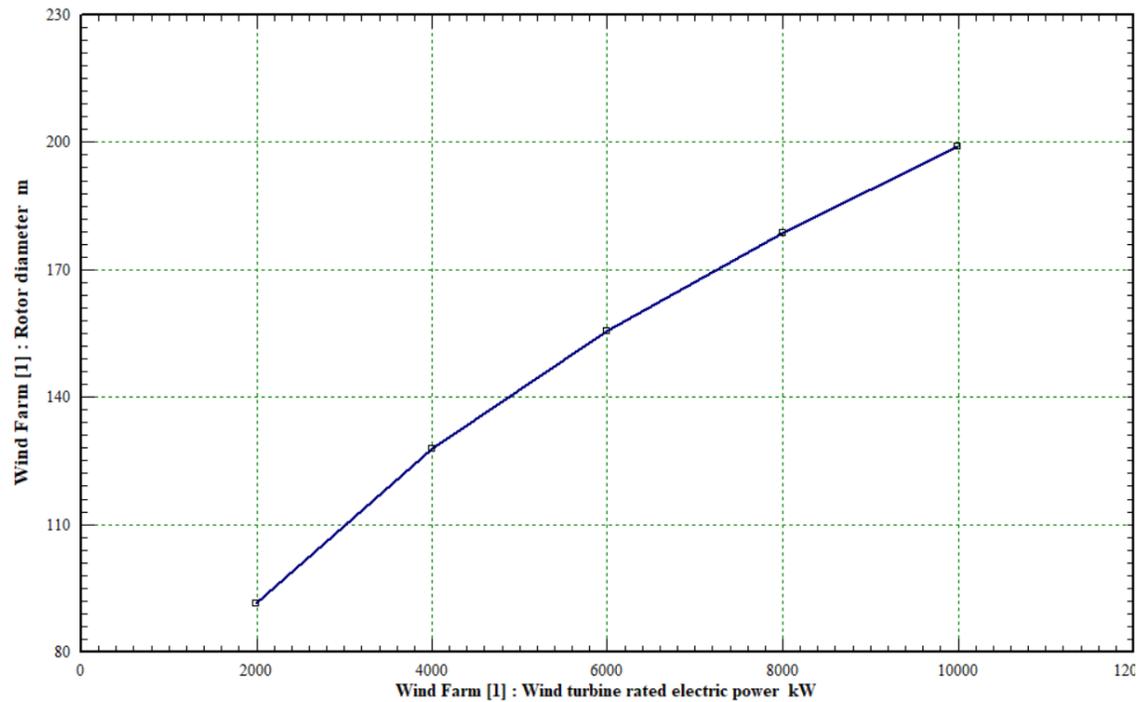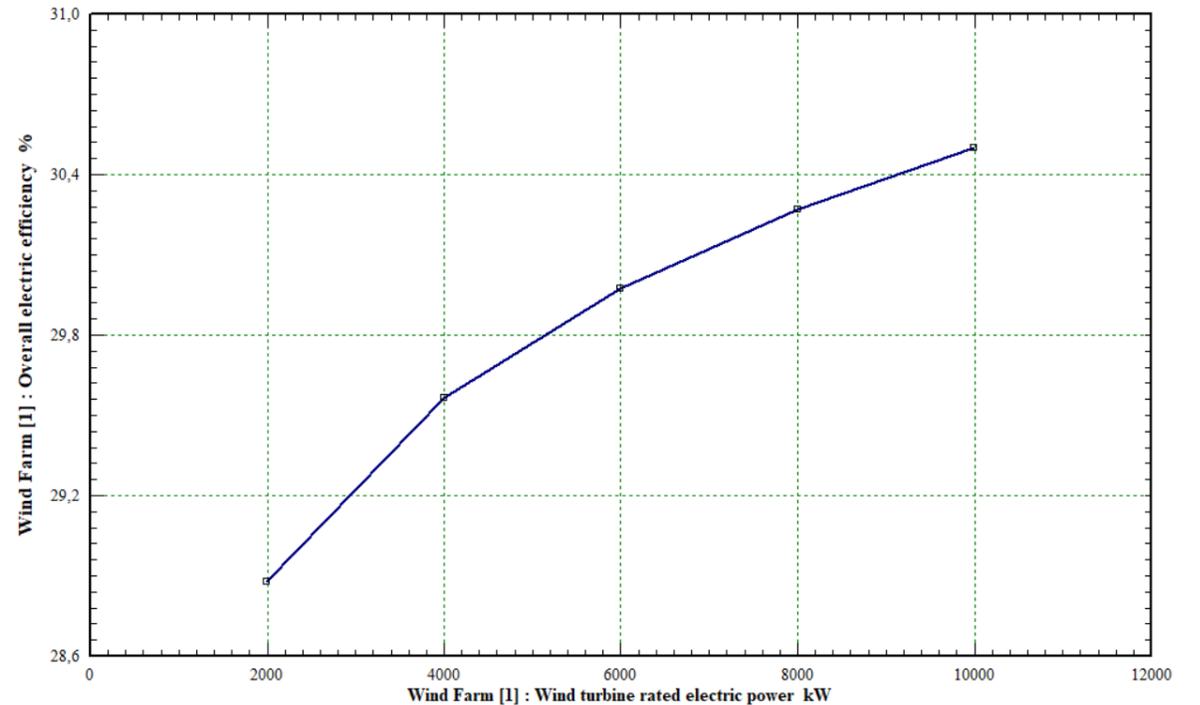
OD Inputs

Main:
- Number of Turbines
- Turbine spacing / Rotor Diameter → Land Area
- Wind Speed: UD @ Hub Height / Wind Resource File

Rating:
- Rated Power
- Rotor Diameter → Efficiency
- Hub Height → Cost & Wind Speed at Hub Height
- Rated point air density (current air density calculated from site menu)
- Wind Speed: rating point, cut-in & cut-out
- Power Curve: Automatic (=TD) / User Defined

Annual Output Estimate(if enabled):
- User Defined Wind Speed at Hub height
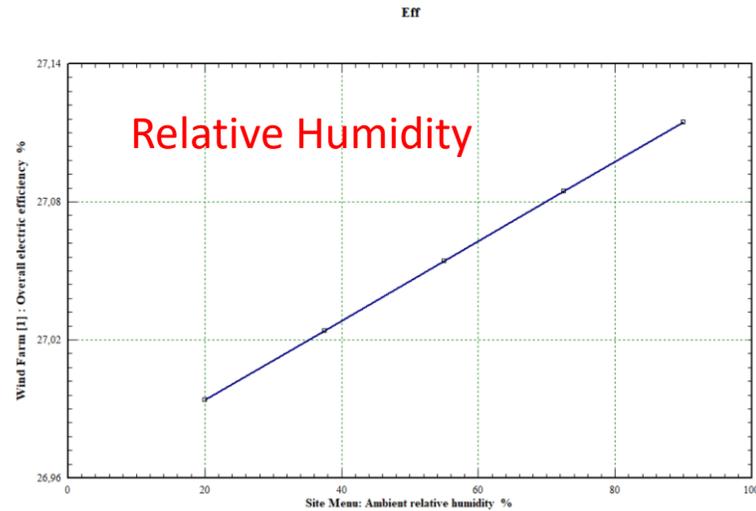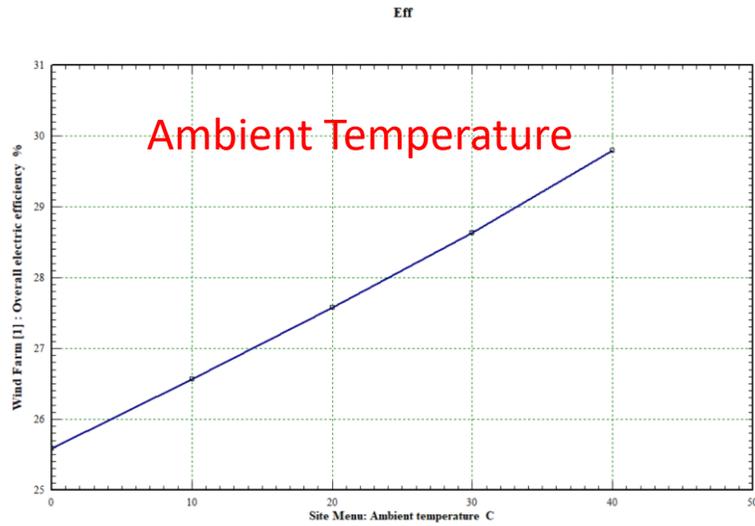- Data from Wind Resource File

User Defined Power Curve

OD Effect of Site Conditions (Air Density)

Ambient Temperature

Relative Humidity
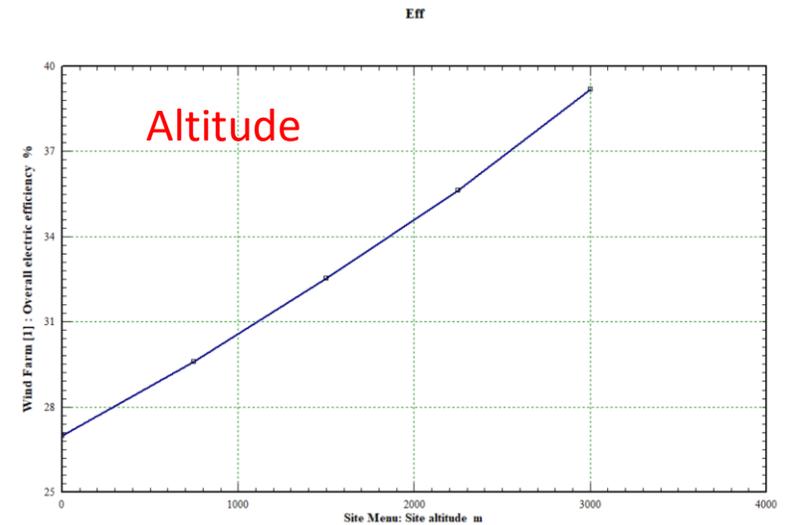
Altitude

Annual Output Calculation from Wind Resource File

Thermoflow Wind Resource File Format

- The Thermoflow wind resource file includes four header lines followed by 8760 data lines.
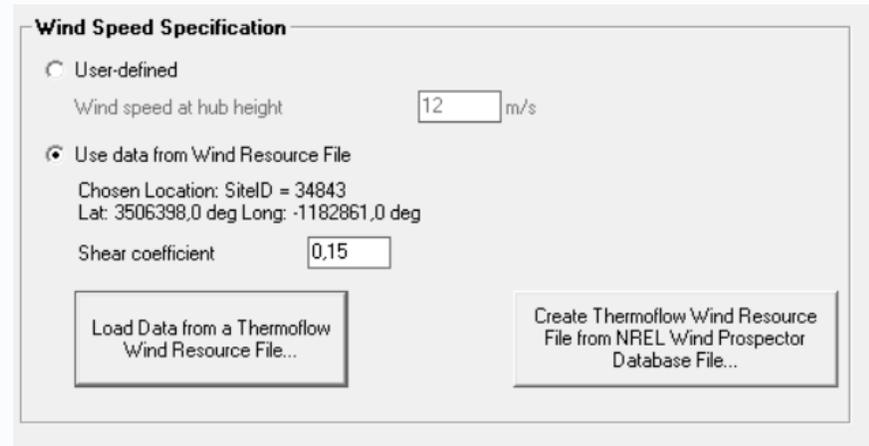
```
"SiteID: 34843"
"Latitude: 35.06398"
"Longitude: -118.2861"
"Hour Number, Day, Hour of the day, Air density at 100m, Wind speed at 100m"
1,1,1,1.06675,7.87275
2,1,2,1.067,7.673
3,1,3,1.0675,7.714166
4,1,4,1.068667,8.2985
5,1,5,1.070417,8.084417
```

- The file is a simple text file using ANSI encoding (one byte per character) where each line ends with a CR LF combination of non-printing characters.

  The first four lines contain metadata to describe the site location and the data header. These lines are enclosed in quotes.

  Line 1 - a site identifier which can be specified by you for reference. In this default file it is the ID number assigned by NREL to this location.

  Line 2 - site latitude in degrees. Positive latitudes are north of the equator.

  Line 3 - site longitude in degrees. Negative longitudes are west of Greenwich, England.

  Line 4 - header describing the wind data listed in lines 5 to 8764. The Hour Number entry is an integer from 1 to 8760. The Day is an integer from 1 to 365. The Hour of the day is an integer from 1 to 24. The Air density at 100m is in units of kg/m^3. The Wind speed at 100m is in units of m/s.

  Lines 5 - 8764 - data lines. Each data item is separated by a comma, and whole numbers use a period as decimal separation. The file must be in that format, regardless of your localized settings which may use a comma for decimal separation or a semi-colon for list separation.

Annual Output Calculation from Wind Resource File

Wind Data from NREL's Wind Prospector

- Go to NREL's wind toolkit website (https://www.nrel.gov/grid/wind-toolkit.html)
- Select the Location and Download a **csv** file → See **Thermoflex Help 24.5.6.1**
- Create a Thermoflow Wind Resource File (***.tfwr**) from NREL Wind Prospector File
- Load Data from a Thermoflow Wind Resource File

* The **Shear coefficient** is used to adjust the database wind speeds from the reference height (100m above ground level) to the turbine actual hub height. Varies from 0,1 to 0,3:

V@hub height = V@100m * (hub height [m] / 100 [m])^Shear Coefficient

Annual Output Calculation from Wind Resource File

2. Estimated Annual Performance		
Estimated annual output for wind farm	223.150	MWhr
Annualized capacity (output / max possible output)	63,68	%
Annualized average wind speed at hub height	11,46	m/s
Number of hours per year that wind turbine operates	7199	hours
Percentage of year that wind turbine operates	82,18	%
Number of hours per year where wind is below cut-in speed	1443	hours
Percentage of year where wind is below cut-in speed	16,47	%
Number of hours per year where wind is above cut-out speed	118	hours
Percentage of year where wind is above cut-out speed	1,347	%
Using data from database		
Site ID	34843	
Site longitude	-1182861	deg
Site latitude	3506398	deg

Annual Output Calculation from Wind Resource File
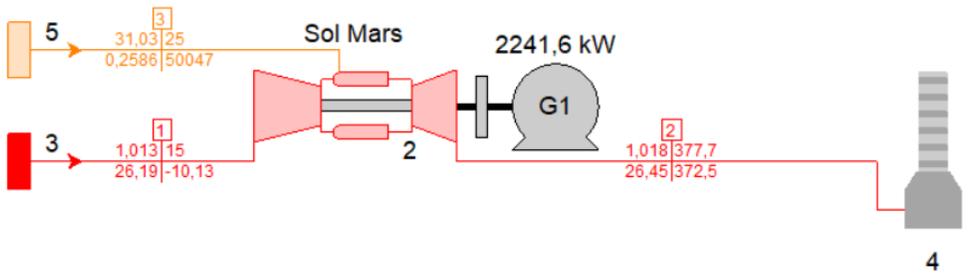

Power
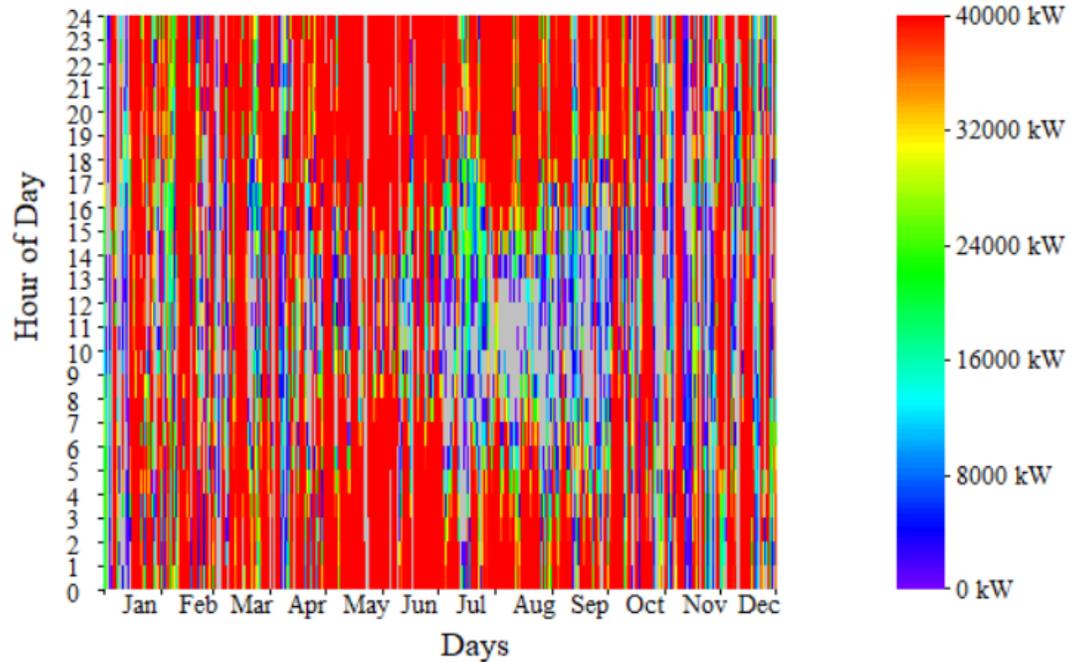
Wind Speed at Hub Height
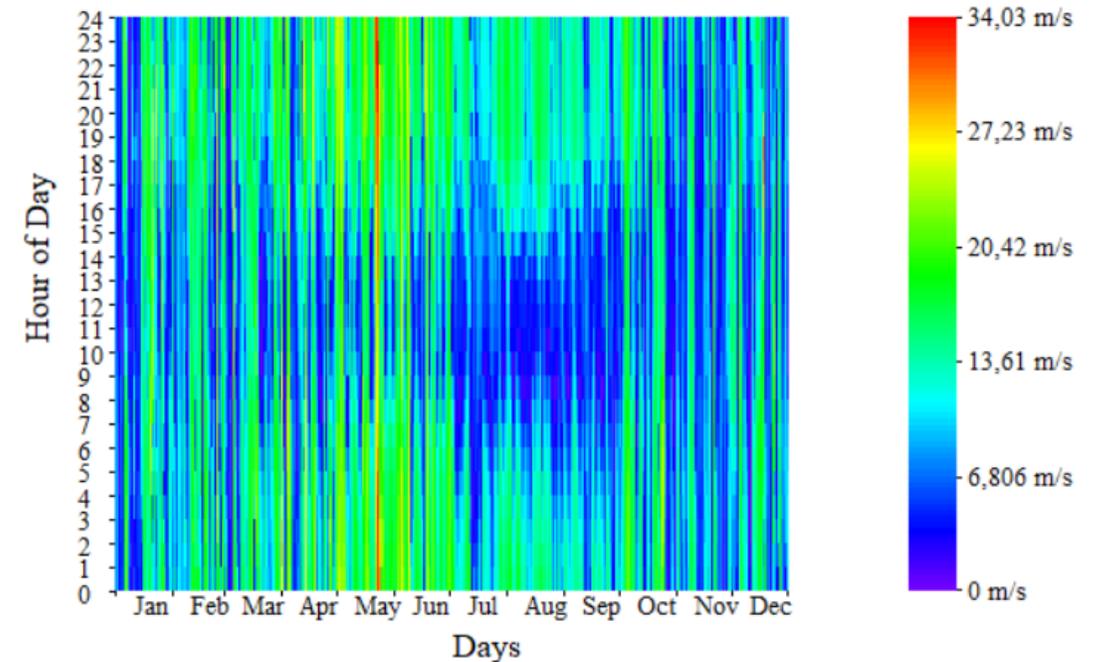
Sample:
(S5-23) WindFarm with Gas Turbine Backup using Scripting
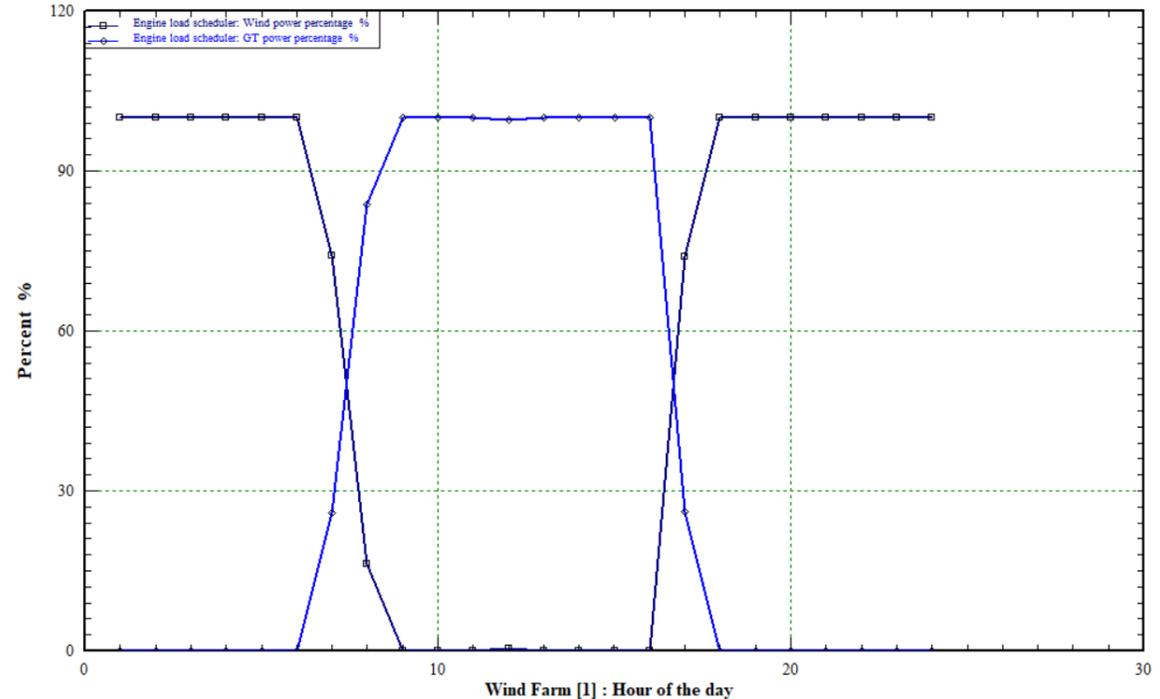
Conclusions

TD Mode:

- Automatic Design of "State of the Art" Wind Farm based on a n. of Turbines and Rated Power
- Initial Estimation of Land required, Annual Output, Wind Turbine Dimensions and Cost
- Initial Comparison of Performance of a Wind Farm at different sites, including Off Shore
- Initial Comparison of Performance and Cost of different Wind Farms at one site

OD Mode:

- Specify data from a Wind Turbine model, from supplier
- Annual Output Estimation from a Wind Resource File, 8760 hours data

Hybrid Plants

- Conventional (GT, Recip. Engine, …) + Wind
- Renewal (Solar Thermal, Solar PV,…) + Wind

Q & A Session

- Please forward your questions on the WebEx Chat

- Further questions by email to: **info@thermoflow.com**

- PP Presentation will be available on the Website / Tutorials
- Video will be available on the Service Center

Thank you!

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