COMPARISON OF THE ACTUAL AND PREDICTED WIND ENERGY PRODUCTION OF A WIND TURBINE USING WINDPRO AND WASP SOFTWARE

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Sustainable Energy Solutions

Introduction

- Wind Turbines are becoming more and more popular in Flagstaff, AZ specifically on Highway 89. Currently four 2.4 KW Southwest Wind Power Skystream wind turbines are deployed in this area.
- The main purpose of this project is to predict the energy output of Mr. Scharf's Skystream wind turbine located on highway 89 shown in Figure 1 . This prediction is then compared to the actual energy production of this specific wind turbine.
- The challenge in this project is that there is no wind data available at Scharf's site. Therefore, wind data is imported from seven different sites near Flagstaff to wind modeling software WindPro and WAsP for required interpolation and wind modeling. Questions of interest:
  - How close is this prediction to the actual energy production?
  - How does the selection of the wind data affect the energy prediction?
  - What sections of Flagstaff are good resources for wind energy?

Figure 1- Skystream3.7 Wind Turbine at Scharf's site

WindPro and WAsP Software

- WindPro is a software used for designing and planning for single wind turbines and wind farms. This software is capable of digitalizing information on maps such as height contour lines or roughness values, simple energy estimation, noise and shadow calculations, and photo montages of the landscapes with wind turbines.
- WAsP is a wind simulation software which calculates energy output based on a linear flow model and is reliant on input wind data. This tool is used to estimate and optimize wind farm energy production generate wind resource maps.
- WindPro is used as the base to import all data into the program and WAsP is in charge of wind or energy simulation and generation of resource maps.
- WindPro and WAsP use the Reynolds-Average Navier-Stokes equation to create a linear model, Wind Atlas, to solve wind flow equations. This Model requires wind data, height contour lines, and Roughness map of the area to calculate energy production of a wind turbine.

Wind Data

- One to four years of wind data was imported to the WindPro software from seven different Meteorological towers around Flagstaff.
  - 0130Anderson Canyon at 10, 30 m
  - 0506 Gray Mountain at 10, 30 m
  - 0702 Gray Mountain at 10, 30, 50 m
  - 7982 Gray Mountain at 48, 59 m
  - 7984 Gray Mountain at 48, 59 m
  - 0503 Mesa Butte at 10, 30, 50 m
  - 5521 Babbit at 10, 30, 50 m
- Figure 2 shows the topographical map of Flagstaff and surrounding along with the site center (Scharf's wind turbine) and met towers. Four digit numbers refer to site ID.
- Wind data files contain wind speed, standard deviation, and direction for every ten minutes.
- WindPro manipulates these wind data and creates wind statistics.

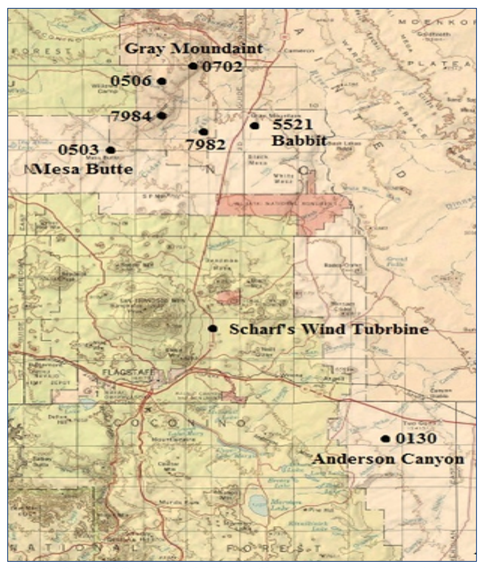

Figure 2- TOPO map of Flagstaff and surrounding with the locations of met towers and the Scharf's wind turbine

Height Contour Lines

- Elevation data is defined in WindPRO in terms of height contour lines.
- These lines are generated by importing Digital Elevation Model (DEM) files of Flagstaff and surrounding to Global Mapper software.
- These files are then exported as a shape file (.shp) which is presented in Figure 3.
- Figure 4 shows the contour lines of the area exported using shape files. The height contour lines are essential since change in height influences the turbulence and consequently the wind profile.

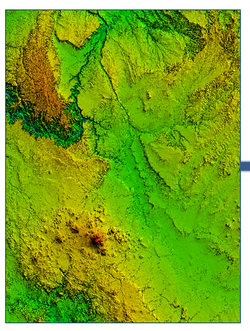

Figure 3- Digital Elevation Model of Flagstaff and surrounding

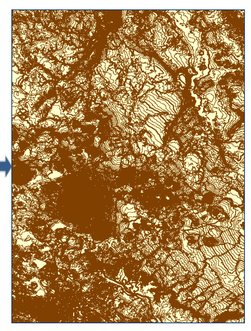

Figure 4- Contour lines created by Global Mapper

Roughness Map

- Wind profile is dependent on the roughness of the surface. Turbulence increases when there is a change in roughness. This changes the height of the internal boundary layer as demonstrated in Figure 5.
- Roughness is classified in different categories and is given certain color and length. This is presented in Table 1.
- Roughness of different sections of Flagstaff and surrounding was estimated by visiting the area and using Google Earth software. The roughness map is presented in Figure 6.

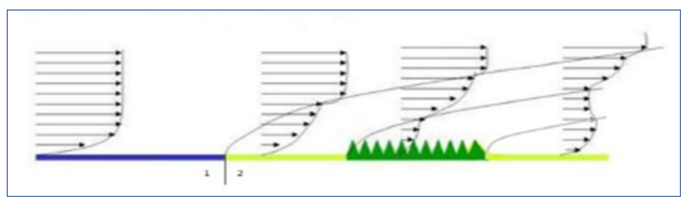

Figure 5- Effects of change in roughness on boundary layer. Any roughness change causes turbulence in the flow. This changes the boundary condition.

Table 1: Roughness type, color and length (Roughness length is 1/30th of the actual length of the elements

Area Type	Color	Roughness Length(m)
City		0.4000
Farmland, partly open		0.1000
Farmland, rather open		0.0548
Farmland, open		0.0300
Farmland, pretty closed		0.2000
Forrest		0.4000
Water inlet		0.0005
Water		0.0000

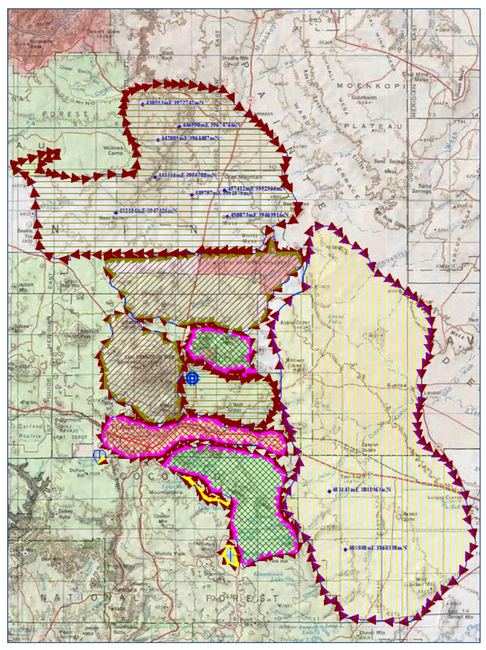

Figure 6: Roughness map of Flagstaff and surrounding. Each area corresponds to the roughness length presented in Table 1.

Basic Research

Results

- Once wind, height, and roughness data was imported to WindPro, WAsP created wind statistics, Energy Production, and a wind map for Scharf's area.

Wind Statistics

- Wind data from all sites was input to WindPro and long term wind climate statistics was created for each site.
- Each of these wind statistics was then interpolated using the roughness and orographic data to predict wind profile at Scharf's site.
- For example, Weibull distribution of wind for Gray Mountain 0702 site is shown in a green line in Figure 7. In the same figure, blue bars represent the prediction of wind speed frequency for Scharf's site. Figure 8 compares the actual wind speed at Gray Mountain 0702 and predicted wind speed at Scharf's site from different directions.

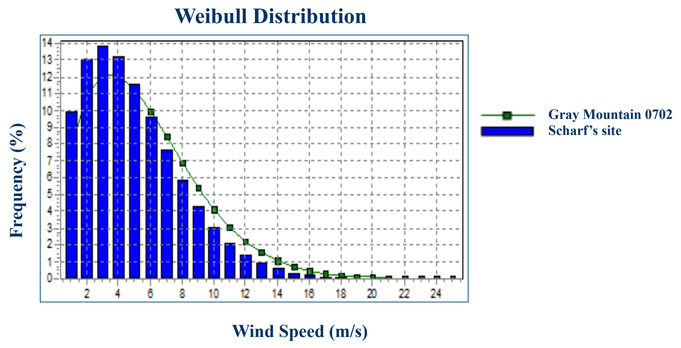

Figure 7- Weibull Distribution of the wind. This figure shows the frequency of wind blowing at different speeds. The green line represents the Weibull Distribution of the Gray Mountain 0702 site and it is comparable to the Scharf's Weibull Distribution in blue columns.

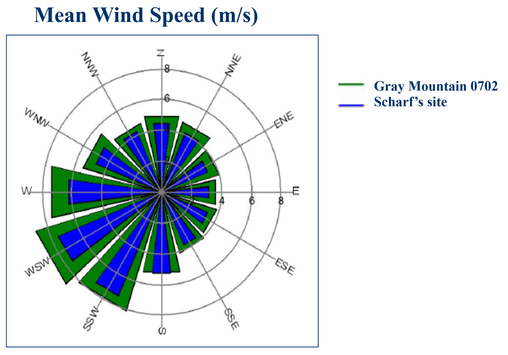

Figure 8- Mean wind speed at different sectors. Wind speed of Gray Mountain 0702 is presented in green and predicted mean wind speed in blue. It can be seen that the dominant wind speed direction is southwest.

Energy Prediction

- Actual energy production of the Skystream3.7 wind turbine at Scharf's site in 2009-2010 was 2.79 KW.
- The power curve for the Skystream3.7 was imported into WindPro and is presented in Figure 9.
- Several cases were considered to predict wind energy in order to compare effects of wind data selection on the prediction of wind energy production. These predictions are shown in Figure 10.
- It was found that selecting wind data at 10 m which is very close to the hub height of Scharf's wind turbine generates 2.8 KW. This is within 0.3% error.
- 0506 Gray Mountain is the windiest site and if used solely, WAsP overestimates the energy production.
- Using all wind data over 48 m poorly estimated the annual energy production. This may be due to underestimation of wind shear.

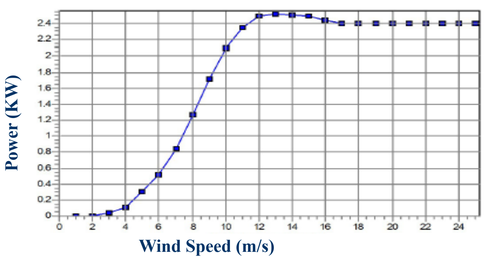

Figure 9- Skystream3.7 power curve. This figure shows power production of the wind turbine at different wind speeds.

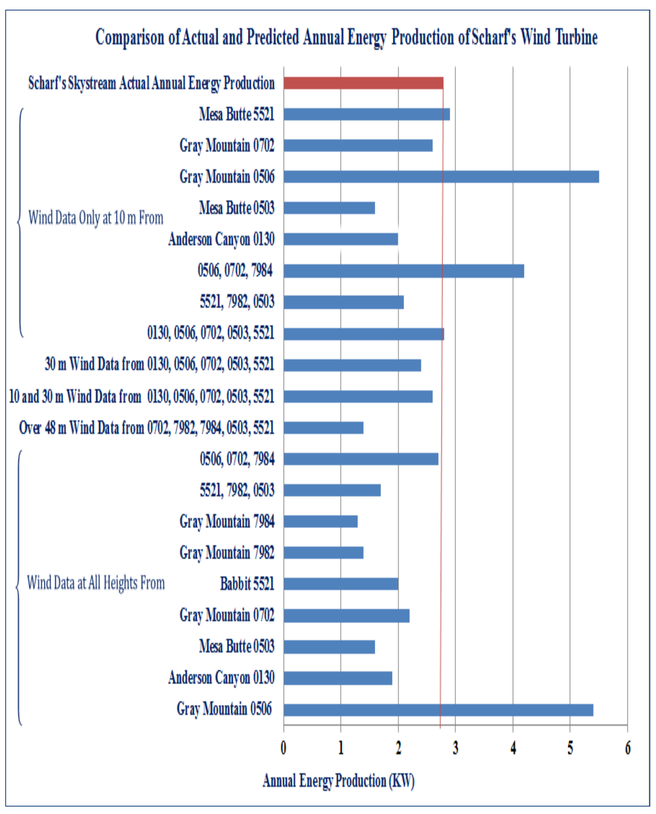

Figure 10- Annual energy production predicted by WAsP using several cases of wind data selections. It was found that choosing wind data at the same height as the wind turbine produces the best result.

Wind Resource Map

A wind map indicates wind speed at different locations on a map using colors. This map is made by running WAsP calculations for each point on the map. The wind resource map of Flagstaff is presented in Figure 11.

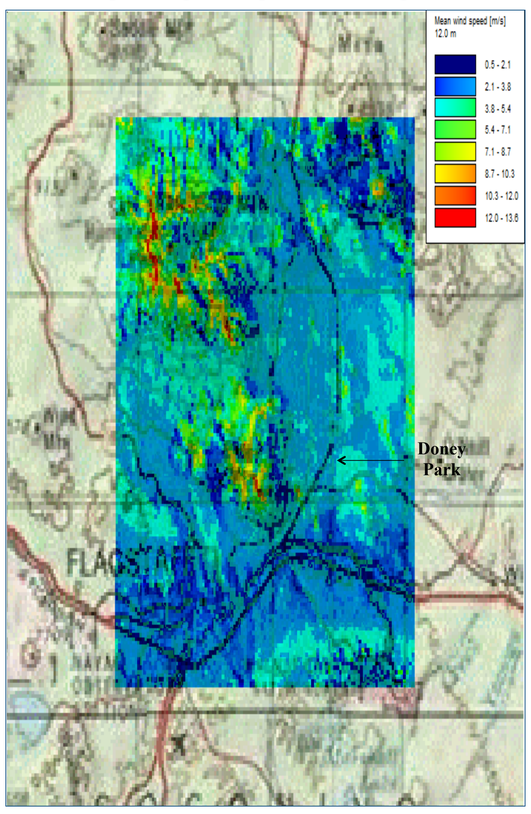

Figure 11- Wind map of Flagstaff at 10 m using WindPro and WAsP software. It can be seen that Doney Park has good potential for small wind.

Conclusion

- WindPro and WAsP can be reliable programs for predicting energy production and wind modeling.
- Energy production was the most accurate when wind data was selected at the same height as the wind turbine.
- The wind map reveals that mean wind speed near the Flagstaff area is mostly between 0.5 to 3 m/s at 10 m above the ground. Doney Park area is a great source for residential wind turbines that are designed to operate with the average wind speed of between 3 and 7 m/s.

References

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