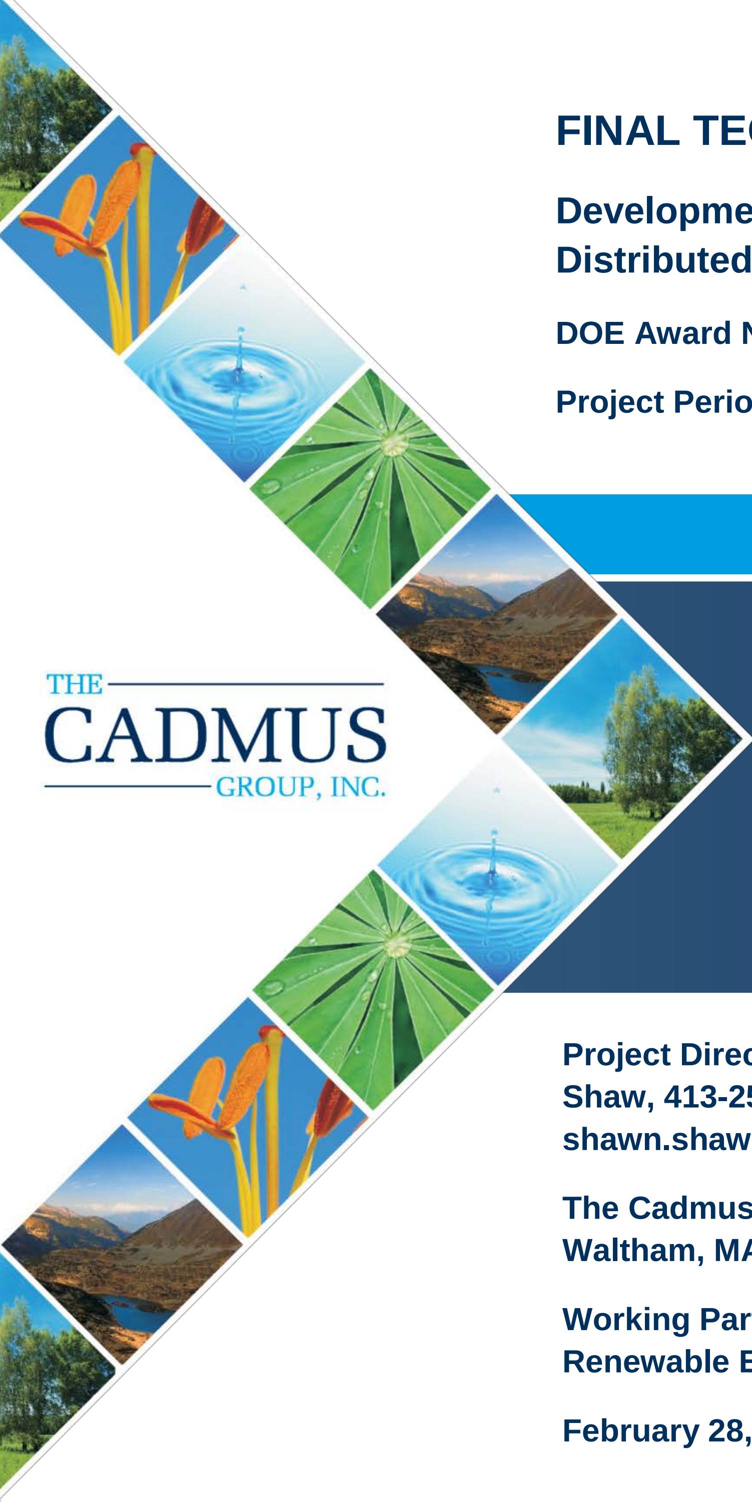


THE CADMUS GROUP, INC.

FINAL TECHNICAL REPORT

Development of a Site Analysis Tool for Distributed Wind Projects

DOE Award No. DE-EE0000498

Project Period (12/09 – 11/11)

Distributed Wind Site Analysis Tool (DSAT)

Project Director/Principal Investigator: Shawn Shaw, 413-258-7247, shawn.shaw@cadmusgroup.com

The Cadmus Group, Inc. 100 5th Avenue, Waltham, MA 02451

Working Partners: Encraft, the National Renewable Energy Laboratory

February 28, 2012

Prepared by:

The Cadmus Group, Inc.
Energy Services Division
100 5th Avenue
Waltham, MA 02451
617.673.7000

Prepared for:

United States Department of Energy (U.S. D.O.E)

Acknowledgment: “This report is based upon work supported by the U. S. Department of Energy under Award No. DE-EE0000498“.

Disclaimer: “Any findings, opinions, and conclusions or recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of the Department of Energy.”

Prepared by:
Shawn Shaw
Mary Knipe
Ryan Kilkenny

720 SW Washington Street
Suite 400
Portland, OR
Tel: 503.467.7100
Fax: 503.228.3696

An Employee-Owned Company
www.cadmusgroup.com

Corporate Headquarters:
57 Water Street
Watertown, MA 02472
Tel: 617.673.7000
Fax: 617.673.7001

This page left blank.

Table of Contents

This page left blank.

EXECUTIVE SUMMARY

Grant Award Number: DE-EE0000498

Recipient: The Cadmus Group, Inc.

Project Title: Development of a Site Analysis Tool for Distributed Wind Projects

Project Director/Principal Investigator: Shawn Shaw, The Cadmus Group, Inc.

Working Partners: Encraft, the National Renewable Energy Laboratory

The Cadmus Group, Inc., in collaboration with the National Renewable Energy Laboratory (NREL) and Encraft, was awarded a grant from the Department of Energy (DOE) to develop a site analysis tool for distributed wind technologies. As the principal investigator for this project, Mr. Shawn Shaw was responsible for overall project management, direction, and technical approach.

The product resulting from this project is the Distributed Wind Site Analysis Tool (DSAT), a software tool for analyzing proposed sites for distributed wind technology (DWT) systems. This user-friendly tool supports the long-term growth and stability of the DWT market by providing reliable, realistic estimates of site and system energy output and feasibility.

DSAT—which is accessible online and requires no purchase or download of software—is available in two account types:

- ***Standard:*** This free account allows the user to analyze a limited number of sites and to produce a system performance report for each.
- ***Professional:*** For a small annual fee users can analyze an unlimited number of sites, produce system performance reports, and generate other customizable reports containing key information such as visual influence and wind resources.

The tool's interactive maps allow users to create site models that incorporate the obstructions and terrain types present. Users can generate site reports immediately after entering the requisite site information. Ideally, this tool also educates users regarding good site selection and effective evaluation practices.

PROJECT GOALS AND ACCOMPLISHMENTS

The Cadmus team's goal for this project was to create an easy-to-use online tool that both evaluates a site's potential for a distributed wind project and produces a site-specific report detailing the energy and environmental impacts of the proposed wind project. To achieve this, the team designed DSAT, a tool to generate key project feasibility indicators, such as the following:

- Energy output
- Project cash flow and return on investment (incomplete)
- Environmental (e.g., carbon-related) benefits
- Aesthetic impacts
- Available wind resource

Currently, the DSAT Website is on line, with over 500 users, and the majority of its functions and features are in place. However, the economics and acoustics features are still in development (as of the end of the term of the grant). The status of the DSAT project tasks is shown in Table 1.

Table 1. Project Tasks

Task Number	Brief Task Description	Status
1	Develop Feature Set and Goals	Completed
2	Supporting Research	Completed
2.1	Wind Tunnel Testing	Completed
2.2	CFD Modeling of Urban Environments	Completed
2.3	Background Research	Completed
3	Tool Algorithm and Mockup Development	Completed
4	Validation Testing of Mockup Tool	Completed
5	User Interface and Database Design	Acoustics and economics unfinished
6	Develop Beta Model of Tool	Completed
7	Final Development	Completed
8	Tool Dissemination	Completed
9	User Support	Completed
10	Future Directions	Completed
11	Project Management and Reporting	Completed

Development Timeline

DSAT was created in a three-phase process.

Phase 1. Research and Development

In Phase 1, the Cadmus team enhanced and expanded our current set of tools to create the more powerful DWT Site Analysis Tool envisioned for this project. Our specific activities for this project entailed the following:

- Conducting extensive background research
- Collecting and analyzing wind resource data
- Developing model parameters for urban and building-mounted installations
- Compiling a list of certified installers
- Developing other tool defaults and inputs

From these efforts, we developed a Microsoft Excel-based mockup for the first round of validation testing. We also developed proof-of-concept screenshots of the major components of the tool.

Phase 2. Testing and Validation

In Phase 2, the Cadmus team conducted validation field trials of DSAT at 95 test sites. We used the data collected from these trials to identify opportunities to improve the model. Meanwhile, our development team created mockups of the graphical user interface (GUI) and designed the database engine for the online tool. Based on feedback from DOE and our industry review panel, we completed development of a beta model. The beta model was vetted by DOE and our industry review panel for function and usability while we conducted a second round of validation testing.

Phase 3. Revisions Based on Test Results and User Feedback

In Phase 3, we worked with DOE and the industry review panel to finalize the beta version of DSAT and create a final version. To address user inquiries, we provided an e-mail-based helpdesk, staffed by personnel knowledgeable in the tool and DWT applications.

After DSAT Is Completed

Once the final version of DSAT was ready to be launched, Cadmus focused on its marketing and dissemination. As is often the case with software, this initial period required a heavier volume of user support, which has diminished over time. We focused on providing responsive service to users and on ensuring that the tool can be maintained with minimal effort after the 2-year contract ends.

Public Release of Website

DSAT was made available to the public on November 4, 2011, at http://dsat.cadmusgroup.com, with the professional license released on January 12th, 2012.

Public Dissemination

Websites for various wind power-related groups contain links to DSAT, as described below.

Wind Powering America

Wind Powering America listed DSAT as a news item on its Website:
http://www.windpoweringamerica.gov/filter_detail.asp?itemid=3425.
Also, DSAT is currently featured in other locations on the site:

- In the right margin of the Wind for Homeowners, Farmers, and Businesses page http://www.windpoweringamerica.gov/small_wind.asp
- At the bottom of the Agricultural and Rural Resources & Tools page (under Software) http://www.windpoweringamerica.gov/agricultural/tools.asp.
- In archived audiovisual files and transcripts of webinar podcasts: http://www.windpoweringamerica.gov/filter_detail.asp?itemid=3255, http://www.windpoweringamerica.gov/filter_detail.asp?itemid=3422, and http://www.windpoweringamerica.gov/podcasts_webinar.asp

National Renewable Energy Laboratory

NREL hosted a webinar on DSAT:
http://www.nrel.gov/wind/smallwind/workshops_webinars.html

DSAT Mentions on Other Websites

http://communitypowernetwork.com/node/207
http://nawindpower.com/e107_plugins/content/content.php?content.9209
http://www.fierceenergy.com/story/dsat-blows-after-3-years-development/2012-01-13
http://eon.businesswire.com/news/eon/20120112005391/en

News About DSAT

http://www.dailyenergyreport.com/2012/01/cadmus-unveils-new-tool-to-improve-siting-practices-for-wind-energy-projects/
http://archive.constantcontact.com/fs078/1101486440047/archive/1109151605659.html

Media Impacts

DOE announced the availability of DSAT in January 2012; Cadmus also issued a press release, which was picked up by numerous business and environmental news outlets, including the following:

- Treehugger
- TMCnet
- MarketWatch
- Virtual Strategy
- Benzinga
- Delicious
- Tweetbuzz
- AOL Energy
- Antea Group
- Daily Energy Report
- Greentechlead.com
- Fierce Energy
- North American Windpower
- Business Wire
- Sustainable Business
- Environmental News Reports

License Types Available

There are two types of licenses available to DSAT users, and the features of each license type are summarized in Table 2.

- ***Standard:*** This free account allows the user to analyze a limited number of sites and to produce a system performance report for each.

- ***Professional:*** For a small annual fee users can analyze an unlimited number of sites, produce system performance reports, and generate other customizable reports containing key information such as visual influence and wind resource.

Table 2. Comparison of DSAT License Types

DSAT License Types	Standard Account	Professional Account
Access to Library of 26 Wind Turbines (2.4kW-2MW)	√	√
Access to Library of 30 Obstruction Types and 8 Terrain Categories	√	√
Ability to Save Completed Projects	Up to 3	Unlimited
System Performance Report	√	√
Visual Influence Report		√
Wind Resource Report		√
Customizable Full Report		√
Cost	Free	$99/Year

Computer Modeling Details

DSAT uses data from wind tunnel tests to generate estimates of the impacts of site-specific features (obstacles and terrain) on the wind resource for a turbine installed at a particular location.

General Description of the Model

Using a combination of user-entered site-specific information, empirical data, and semi-empirical data, DSAT estimates the wind resource potential for a specific site and, from that estimate, predicts the annual electrical generation for a typical year for a variety of wind turbine configurations. Currently, the DSAT library contains information on 26 turbines, which range in energy production capacity from 2.4 kW to 2 MW.) (See Appendix A for further details on the general function and workflow of the model.)

Coverage

DSAT contains wind data for 40 states, as shown below. For those states without wind data, DSAT provides a PDF copy of the state-level wind map.

Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Georgia
Hawaii
Idaho
Indiana
Kansas
Kentucky
Maine
Maryland
Massachusetts
Michigan
Minnesota
Missouri
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New Mexico
New York
North Carolina
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
South Carolina
Tennessee
Utah
Vermont
Virginia
Washington
West Virginia
Wisconsin
Wyoming

DSAT's terrain and obstacle libraries cover a variety of potential site configurations. (See Appendix A for details.)

Performance Criteria

The primary output of the DSAT model is an estimate of annual electrical production (AEP, kWh) from the proposed wind project. In addition, DSAT calculates the following:

- Hub height wind speed
- Turbine line of sight to the surrounding area
- Environmental benefits resulting from offset consumption of electricity that would have been generated using regional generation source mixtures

The primary metric used to evaluate DSAT's performance is AEP, as this is readily comparable to observed energy generation, obtained through onsite metering of turbine electricity yield.

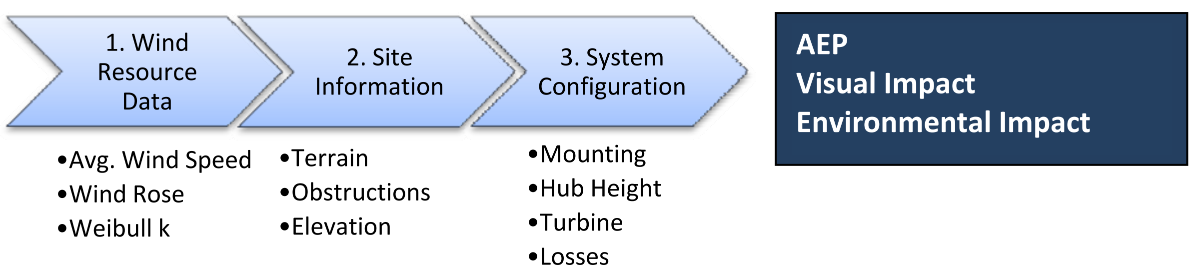
Test Results

Cadmus compared DSAT's predicted AEP values against the AEP values from installed wind energy projects. For a population of 39 wind projects for which Cadmus was able to obtain accurate performance data, DSAT predicts overall AEP with an error of less than 2 percent. (The results of this analysis are summarized in Appendix B.)

Model Theory

DSAT uses data from a variety of sources in the process shown in Figure 1.

Figure 1: DSAT Data Flow



Overview of the DSAT Calculation Process

Using these data, DSAT performs the following steps once a turbine site is chosen:

1. It references the database to determine wind speed, elevation, "wind rose" (a graphic that shows general wind direction and speed at a location), and other pertinent data.

2. It divides the site into 16 directional sectors, corresponding to a typical wind rose configuration.

3. It estimates the net AEP for each direction sector using the following process:

    a. Referencing the terrain library to obtain wind shear and effective ground level data for the user-selected terrain type (e.g., suburban, dense forest, cropland).

b. Referencing the obstruction library for wake effect data, based on user-selected obstructions.

c. Calculating the effective hub height of the turbine.

d. Referencing the nearest, but next highest, wind speed layer in the database.

e. Applying the wind shear value from the terrain library to adjust the wind speed layer data to the corrected turbine hub height.

f. Applying obstruction wake effect values to predicted annual average wind speed.

g. Applying annual average wind speed to a Weibull distribution to calculate a histogram of wind speed values for the site.

h. Combining this histogram of wind speeds with the selected turbine's power curve to calculate a raw estimate of AEP.

i. Applying any relevant losses (user-entered) to the raw AEP.

4. DSAT then combines each AEP estimate into a total for the site.

5. It generates an estimate of environmental benefits by multiplying the AEP estimate by state-level emissions factors for various air pollutants.

6. It uses elevation and obstruction data to generate a line-of-sight analysis for assessing turbine visibility.

Hardware Requirements

DSAT works on any computer that can run Microsoft Silverlight software. Table 3 shows the minimum requirements, according to the Microsoft Silverlight Website.

Table 3. Minimum System Requirements

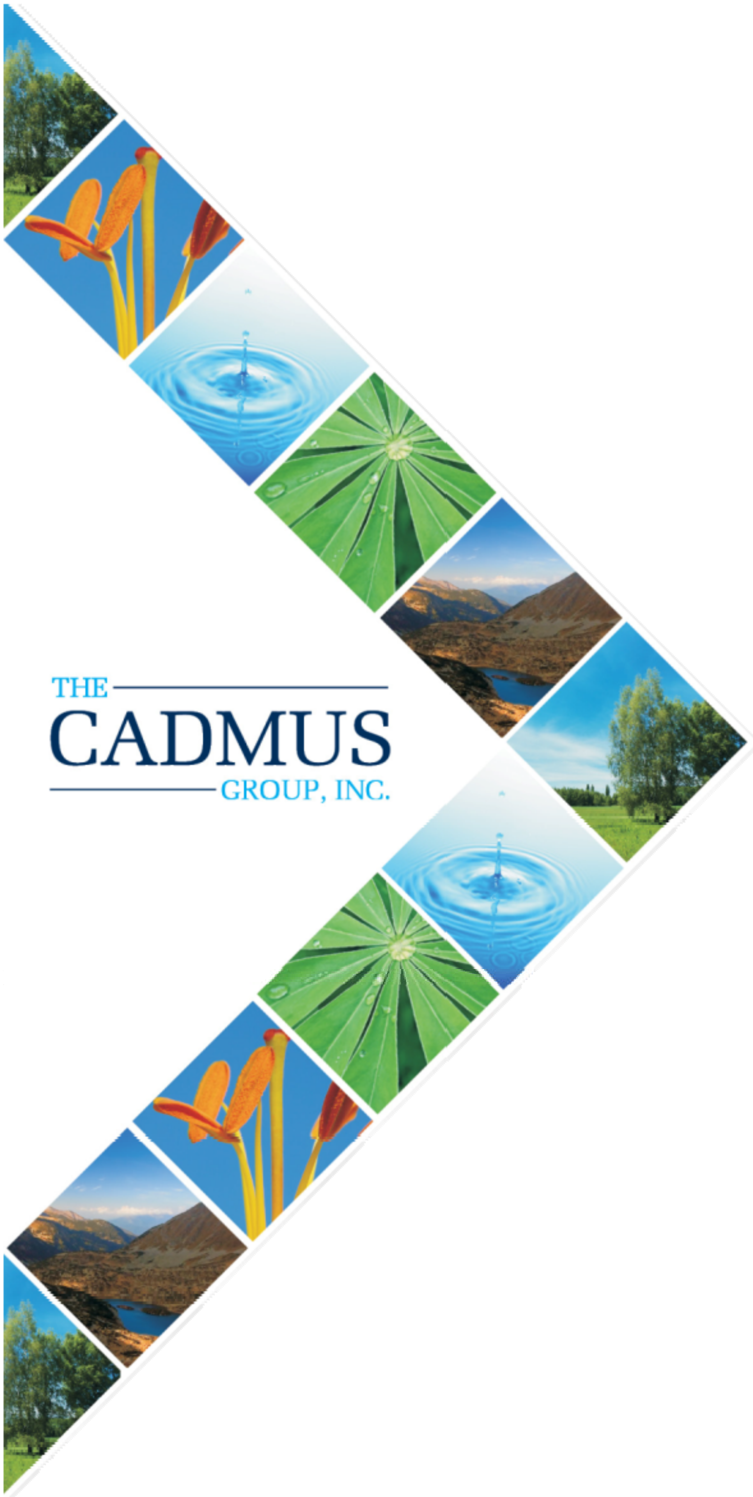
Components	Requirement
Windows	x86 or x64 (64-bit mode support for IE only) 1.6-gigahertz (GHz) or higher processor 512 MB of RAM
Macintosh (Intel-based)	Intel Core Duo 1.83- GHz or higher processor 512 MB of RAM

Relevant Documentation

The DSAT User Guide is posted on the DSAT Website's Help page and provided in Appendix A of this report. The guide contains step-by-step instructions and features screen captures from the DSAT user interface.

The DSAT Website also contains a Frequently Asked Questions (FAQ) section, which the Cadmus development team updates often.

APPENDIX A. DSAT USER GUIDE



THE CADMUS GROUP, INC.

DSAT User's Guide
(Distributed Wind Site Analysis Tool)

February 27, 2012

Prepared by:

The Cadmus Group, Inc. / Energy Services
57 Water Street
Watertown, MA 02472

617.673.7000

Prepared for:

United States
Department of Energy

Manual applies to DSAT v1.0

Manual Release Date: 10/28/2011

Manual First Revision: 2/27/2012

For comments or questions: dsat@cadmusgroup.com

Table of Contents

Figures

Tables

Disclaimer

The Distributed Wind Site Analysis Tool (DSAT) was created to streamline and improve the process for siting distributed wind projects. DSAT uses a variety of publicly available and privately generated data, user input, and relevant assumptions. Many of these factors vary considerably from project to project. DSAT is intended as an informational tool only and users should consult a wind energy professional before making any financial decisions regarding a potential wind energy project. Neither the development team nor the U.S. Department of Energy is responsible for the results generated through the use of this tool.

Introduction

The Distributed Wind Site Analysis Tool (DSAT) is a tool for conducting detailed site assessments for single turbine projects, from residential to community scale. DSAT was created by a partnership between The Cadmus Group, Inc., Encraft, and the National Renewable Energy Laboratory (NREL). The development of DSAT was funded through a grant from the United States Department of Energy (DOE), award number DE-EE0000498, under the Wind Powering America program.

DSAT was created to address the needs of the distributed wind energy community through:

- Accurate prediction of project energy yield
- Standardized reporting of system characteristics, benefits, and impacts
- Education of distributed wind consumers and industry newcomers regarding system siting and wind resource prediction

This DSAT User's Guide contains explanations and procedures for using DSAT version 1.0 to assess a site's potential wind resource availability and to estimate the potential electricity production of a wind energy conversion system for that specific site. This primary audience for this guide consists of grant applicants, municipal planners, property owners, educational institutions, students, and wind system installers.

About DSAT

DSAT is a fully featured online tool that uses an intuitive map-based interface to give users unprecedented control over micro-siting. Key features include:

- Library of nearly 30 individual obstruction types, including vegetation, buildings, and terrain features that can be "dragged and dropped" onto a map of the proposed site
- Included data for 25 wind turbines, from residential scale to multi-Megawatt class machines
- Built in wind resource database, using 200m x 200m resolution data at multiple heights
- DSAT wind data from publicly available NREL validated wind maps generated by AWS Truepower in 2003
- Site and wind resource characteristics developed from real-world wind resource and turbine performance data, detailed information on energy yield, environmental impacts, and turbine visual influence, visually appealing and comprehensive report, suitable for distribution to project stakeholders, grant funding agencies, municipal authorities, and other interested parties

Section 1. Using DSAT

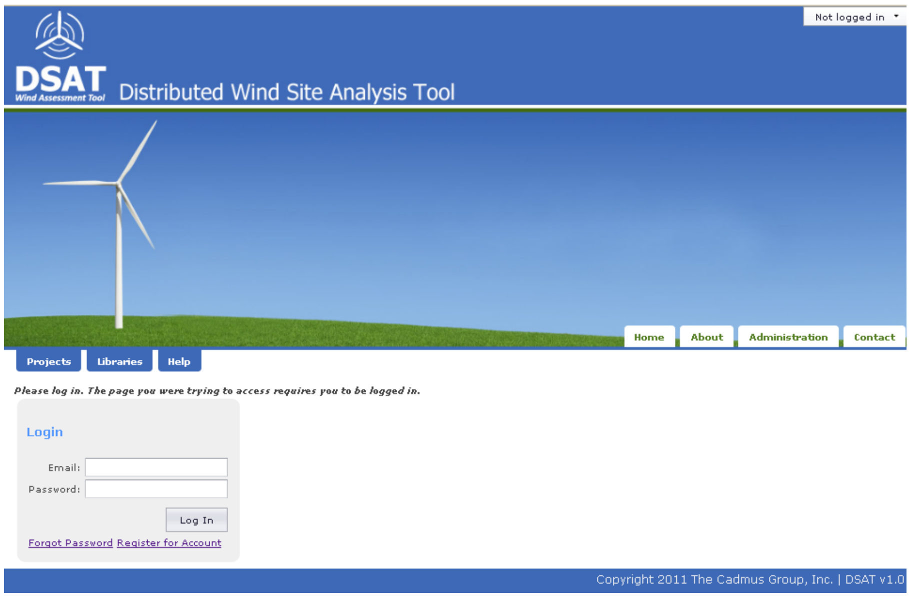
These pages illustrate the process for accessing DSAT and using the application.

Steps for Using DSAT

Step 1. Access the DSAT Application

Open a browser and navigate to http://app.dsat.cadmusweb.com. The Web page shown in Figure 1 will display.

Figure 1. DSAT Web Interface



Step 2. Register

a. Click at upper right corner **Not logged in** to display the New User Registration Screen (Figure 2).

b. On the New User Registration Screen, type your e-mail address, create a password, and then confirm it by retyping it in the second field.

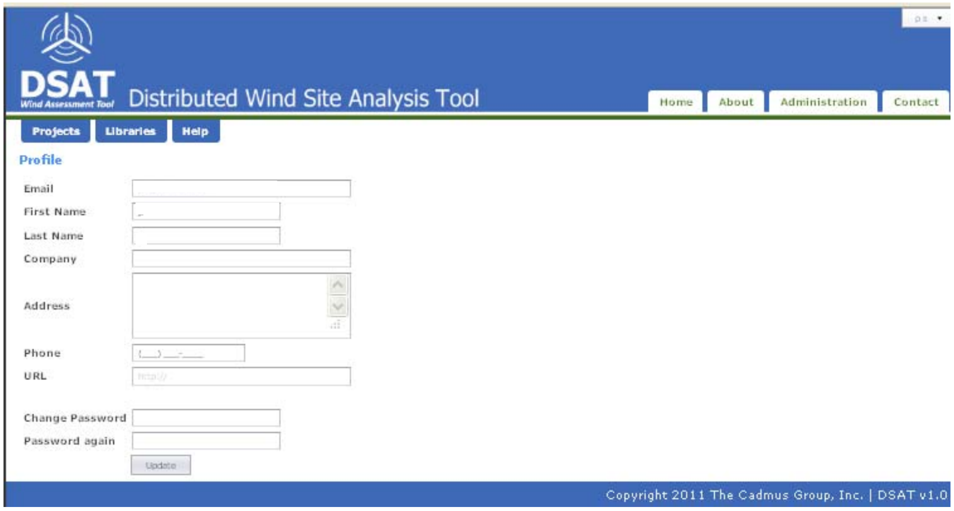
Figure 2. New User Registration Screen

c. Type the security code as you read it.

d. Click **Register**.

e. Type the requested information into the registration form (Figure 3). When the form is completed, click **Update** to complete your registration.

Figure 3. DSAT Registration Page Window

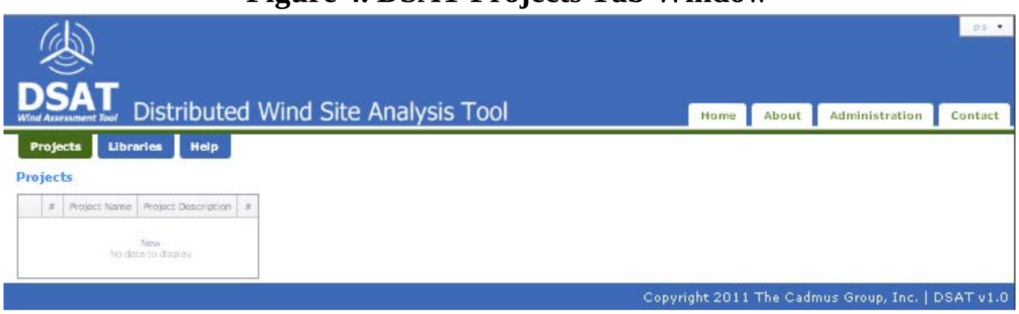


Step 3. Create a Project

A project can contain one or several sites. Usually, a project contains related sites or variations of a turbine system configuration.

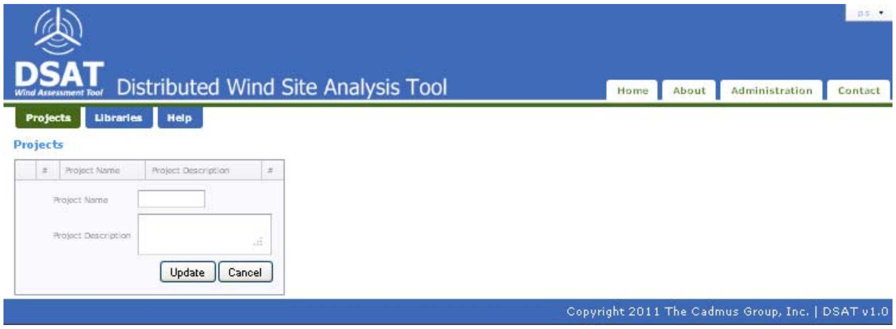
a. Click the Projects tab to open the Projects window (Figure 4).

Figure 4. DSAT Projects Tab Window



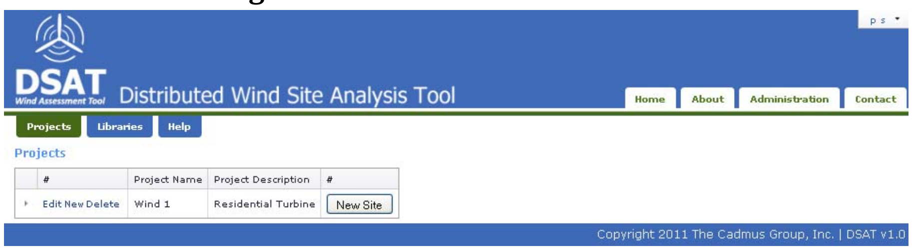
b. Click **New** to create a new project (Figure 5). Enter a project name and description, then click **Update** to save the project.

Figure 5. DSAT Create Project Window



c. Click **New Site** (Figure 6) to create a site within the project folder created in the previous step. The Site Configuration Welcome screen will display.

Figure 6. DSAT New Site Window



Step 4. Create a Site Configuration

a. Click **Next** at the bottom of the Site Configuration welcome screen (Figure 7).

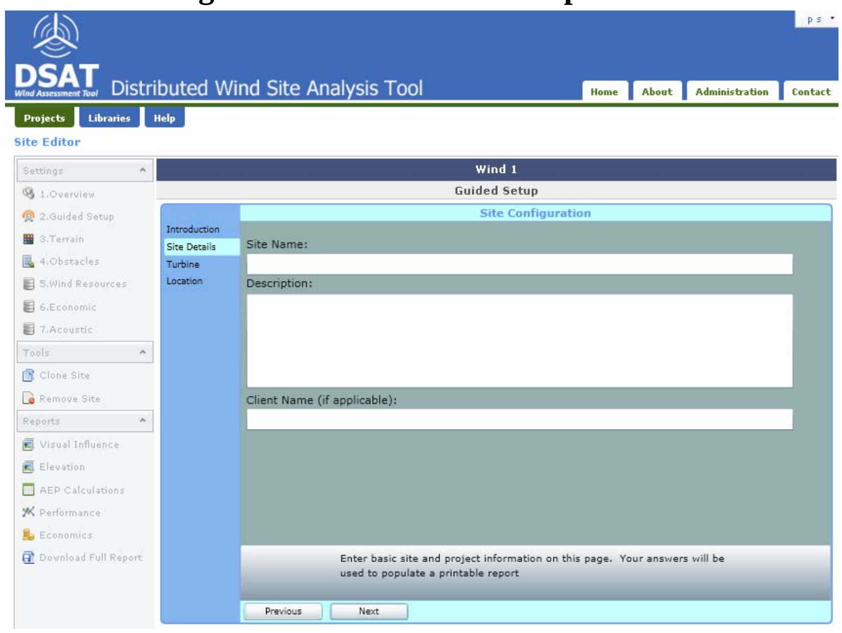
Figure 7. DSAT Guided Setup Introduction

The first Guided Setup screen (Figure 8) will display.

NOTE: You can group multiple sites in a single project folder. For example, you may explore different turbine configurations for a single site or estimate the performance of a particular turbine at multiple locations on the same site for comparison.

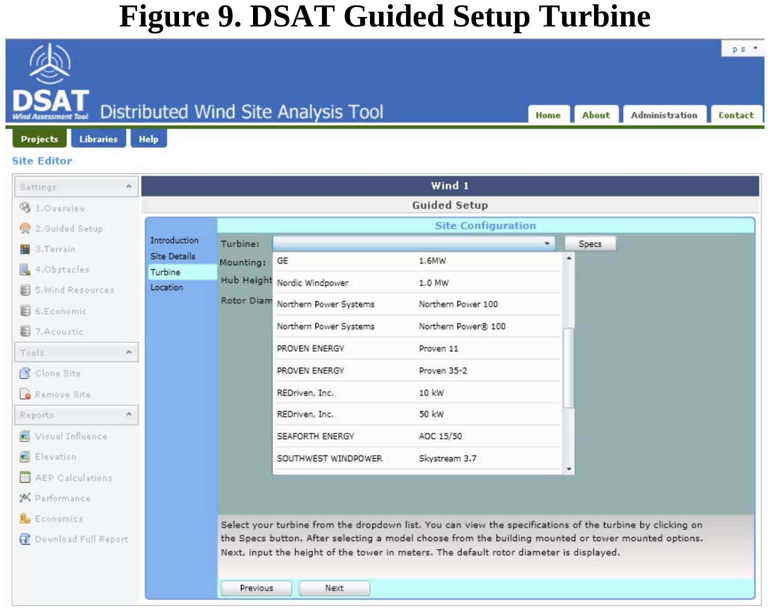
b. Type the site name (required) and the description (optional) and then click **Next**. This information will appear in the printable report.

Figure 8. DSAT Guided Setup Name



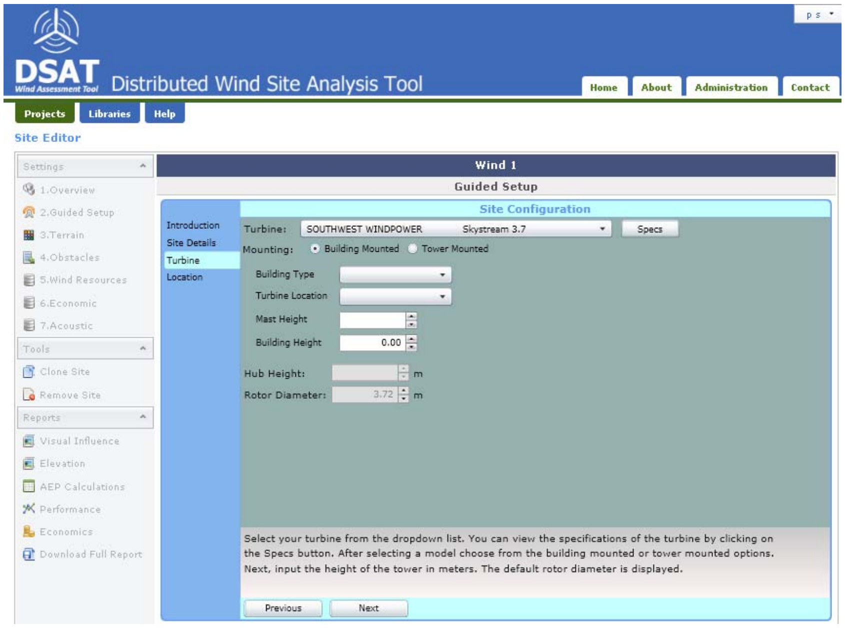
c. Choose a turbine from the pull-down menu (Figure 9).

Figure 9. DSAT Guided Setup Turbine



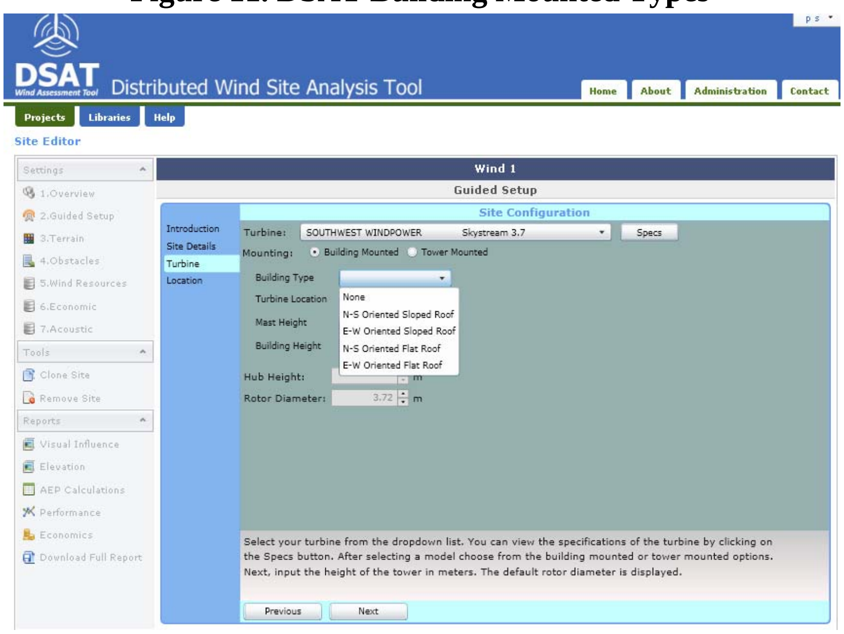
d. Choose the mounting type: building or tower. A building mounted turbine requires some details about the installation (Figure 10).

Figure 10. DSAT Building Mounted Options



NOTE: The "building type" is the orientation of the roof: N-S, E-W, flat roof, or a sloped roof (Figure 11).

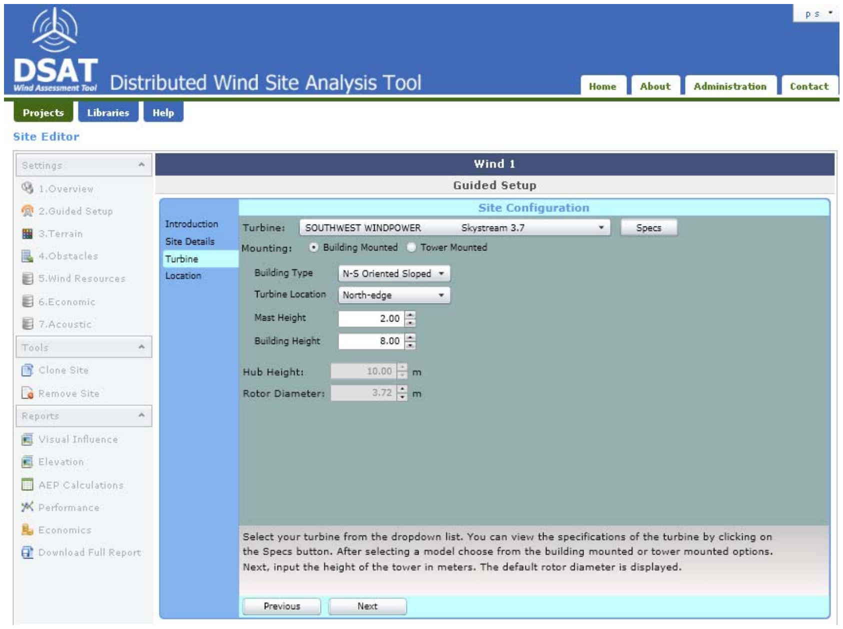
Figure 11. DSAT Building Mounted Types



NOTE: The "turbine location" or placement on the roof is where the turbine will be located on the roof relative to extents of the roof and the compass direction: middle, north-edge, south-edge, etc.

e. Enter a mast height appropriate for the turbine that is chosen (Figure 12).This is the height of the turbine hub above the roof. The “building height” is the height of the roof to which the turbine mast will be mounted.

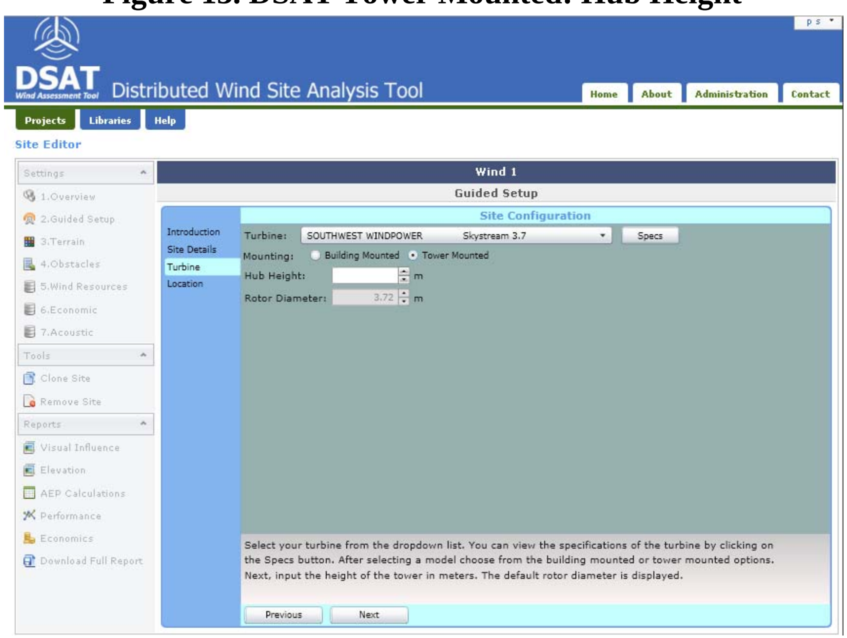
Figure 12. DSAT Building Mounted: Mast and Building Heights



f. If you chose the Tower-Mounted option, specify a hub height (Figure 13).

NOTE: Turbine specifications often indicate commonly used tower hub heights for that model.

Figure 13. DSAT Tower Mounted: Hub Height

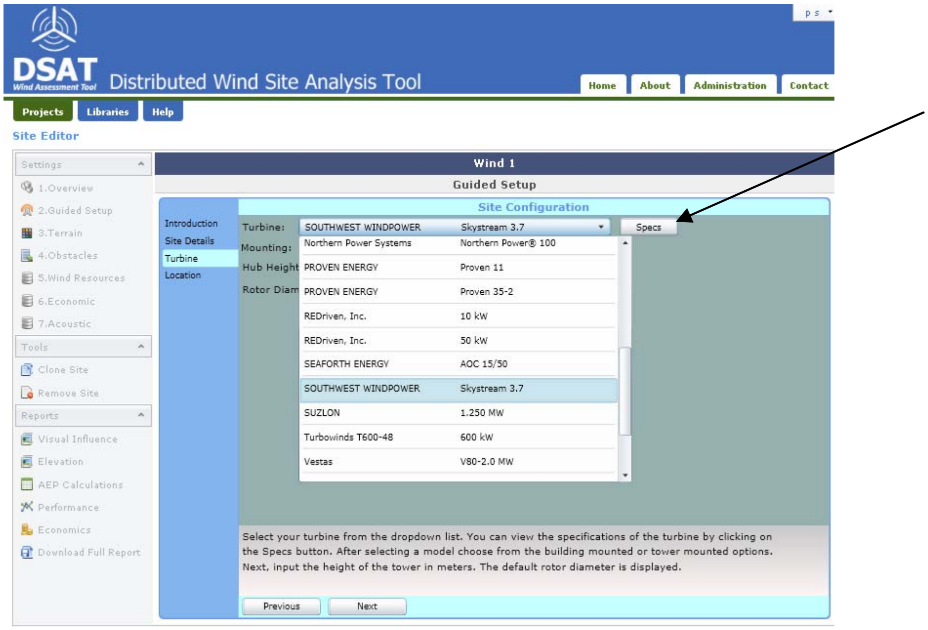


NOTE: To access the Wind Turbine Library for details, click the Libraries tab, located to the right of the Projects tab in DSAT (Figure 14). (This wind turbine information is also in Appendix B.)

Figure 14. DSAT Libraries Tab

g. From the drop-down menu of available turbines (Figure 15), click the Specs button to display the specifications of the selected turbine.

Figure 15. List of Turbines



The details of the selected turbine are shown in Figure 16.

Figure 16. DSAT Turbine: Specs

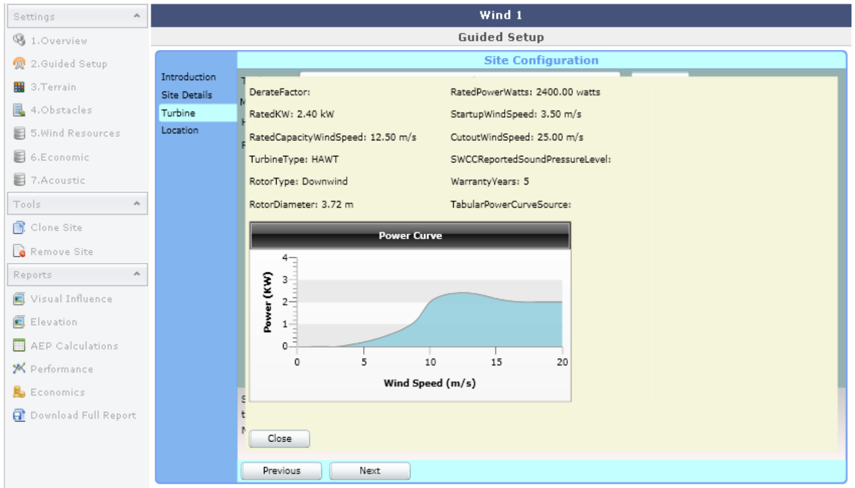
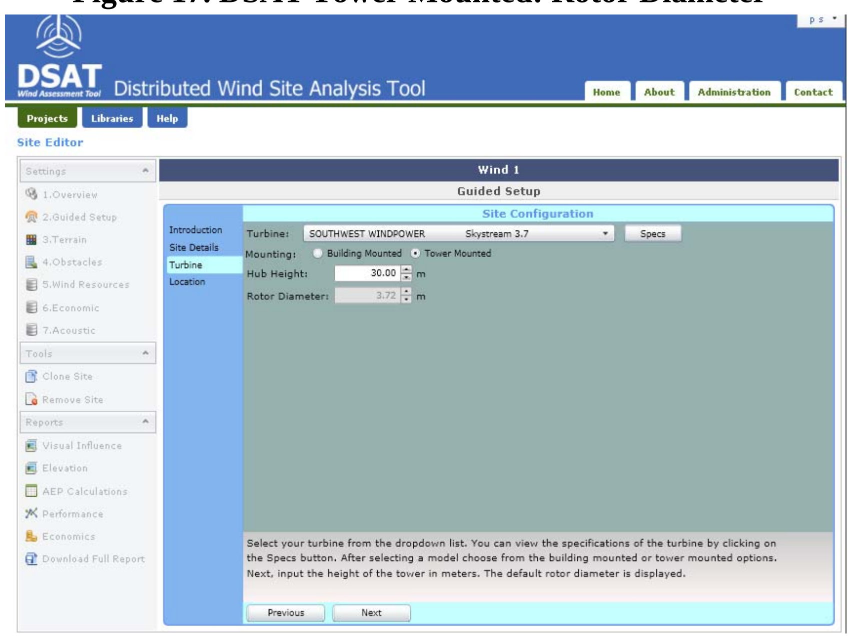


Figure 17 shows the rotor diameter default for the chosen turbine.

Figure 17. DSAT Tower Mounted: Rotor Diameter

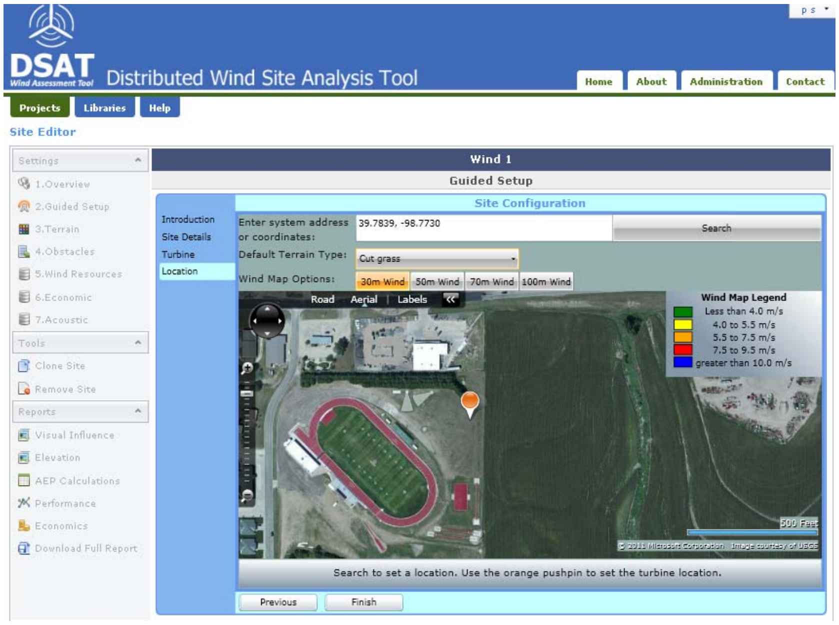


h. Click **Next** to store your selections and display the Location page.

Step 5. Specify the Site Location

a. On the Location screen (Figure 18), type the street address or coordinates in decimal degrees and click Search to zoom to your site's location.[1]

Figure 18. DSAT Guided Setup Location



b. Choose the default terrain type from the pull-down menu.

c. View the wind resource at different heights by selecting one of the Wind Map Options buttons (30m, 50m, 70m, or 100m) and clicking "Refresh Wind Resources." (***NOTE:*** Wind speed values are given in 200 meter resolution squares; so move your cursor over the individual squares to view the estimated wind resource.)

d. Use the scroll-wheel on the mouse, or the zoom bar at left of the screen to zoom in on your site. Click and drag the orange pin to specify a new location.

NOTES: To display an aerial map or a road map of the site, click the appropriate button beneath the Wind Map Options tabs at the top left of the viewing window. To display an aerial map containing the names of roads, towns, cities, etc., click the Labels button.

e. Click Finish to save your site specification.

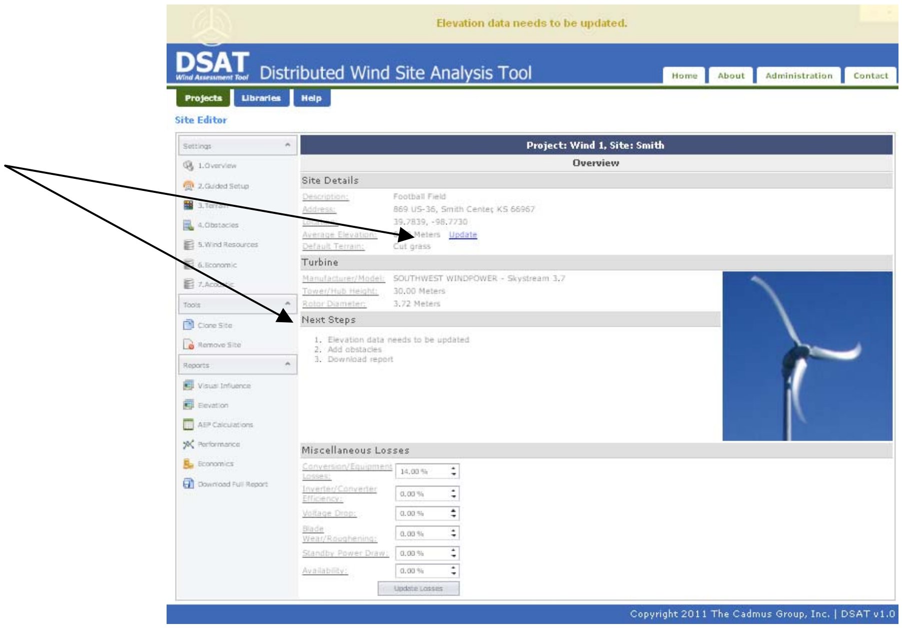
[1] When entering coordinates, first enter the site's latitude and then its longitude, latitude and longitude may be separated by a space, comma, or semi-colon. The longitude must be preceded by a negative sign (-) if the site is located in the western hemisphere.

Step 6. Review Site Overview

The Project Overview screen (Figure 19) displays site details and chosen turbine, the next steps to be completed, and the miscellaneous losses. Under the Next Steps heading, the first item is, “Elevation data needs to be updated.”

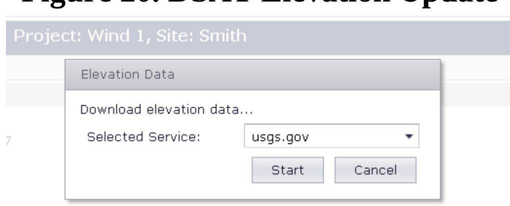
a. Click the Update link.

Figure 19. DSAT Project Overview



b. When the Elevation Data window opens (Figure 20), click the pull-down menu that lists the GIS data services available within DSAT (USGS and Google). Click to select either of these services to acquire the average elevation of the site and press Start.

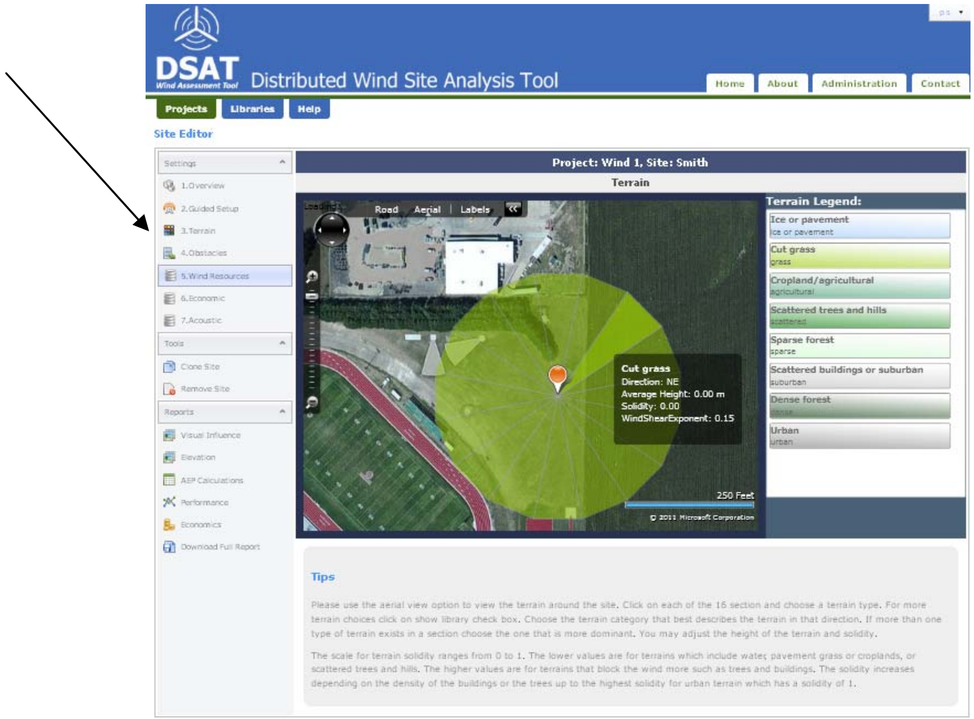
Figure 20. DSAT Elevation Update



Step 7. Specify Terrain Types and Obstacles

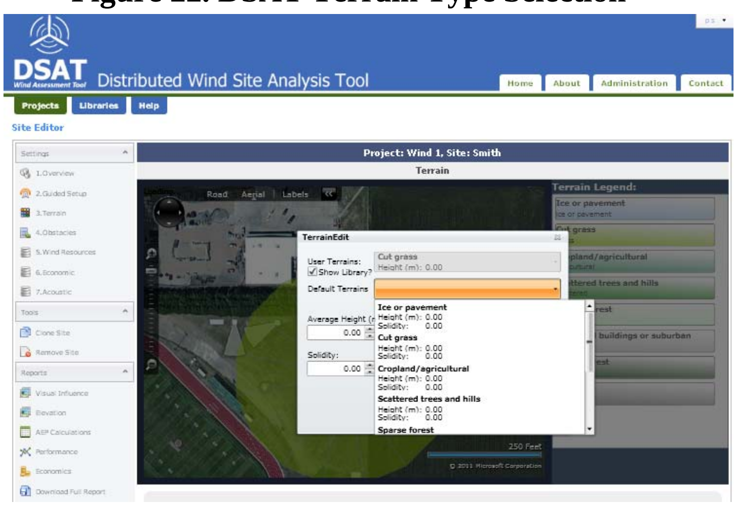
a. Click Terrain in the left column to display the Terrain screen (Figure 21[2]), which divides the site into 16 sectors.

Figure 21. DSAT Terrain Sections



b. Specify the predominant terrain type in each section by clicking on a pie section. This opens a dialog box listing common terrain types (Figure 22).

Figure 22. DSAT Terrain Type Selection



[2] The aerial view option is well-suited for terrain and obstacle evaluation.

NOTES: This opens a dialog box that lists the common terrain types. If the site has a terrain type other than the default, click Show Library and select the appropriate terrain type from the pull-down menu. You can also change the default canopy height and solidity of the terrain.

Canopy Height. When describing terrain, the canopy height is the average height of the top of the terrain feature. For example,

- An urban terrain made up of 20m tall buildings would have a canopy height of 20m.
- A forest with trees ranging from 10m to 20m tall would have an average canopy height of 10m-20m.

Solidity. This is a measure of the degree to which the wind is blocked by the terrain and is represented by a number from 0 (completely open) to 1 (completely obscured). Densely packed buildings, for example, might completely block the flow of wind, while a forest will allow some air to move through tree branches and undergrowth, which is reflected by forest terrains generally having a solidity of less than 1(Table 1).

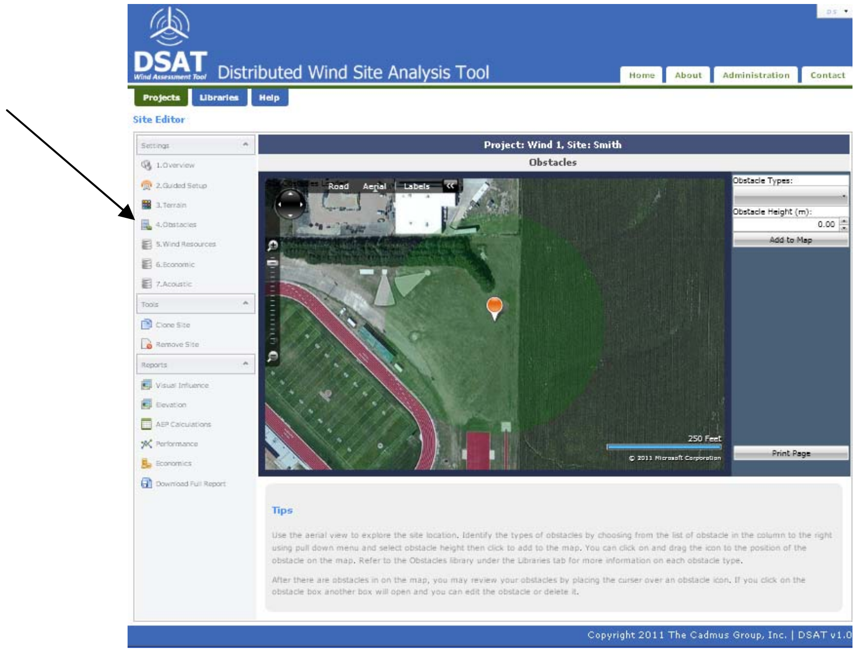
Table 1. Terrain Types and Solidity

Terrain Name	Solidity
Ice or pavement	0
Cut grass	0
Cropland/agricultural	0
Scattered trees and hills	0
Sparse forest	0.56
Scattered buildings or suburban	0.76
Dense forest	0.66
Urban	1

c. Type the average height and solidity, if these differ from the default values.

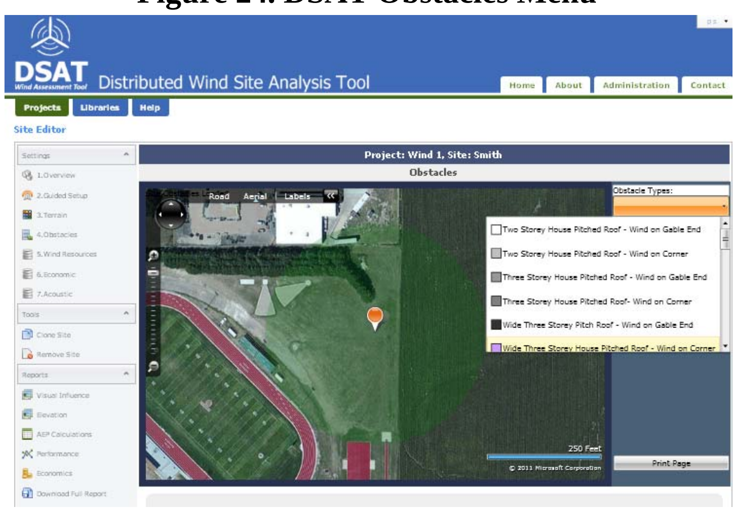
d. Click **Obstacles** in the left pane to display the Obstacles screen (Figure 23).

Figure 23. DSAT Obstacles Window



e. Click the pull-down menu under Obstacle Types (Figure 24) to add an identified obstacle to the map.

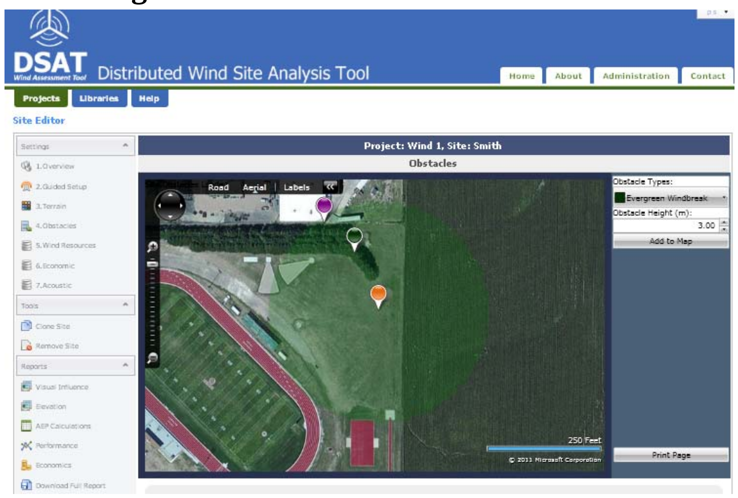
Figure 24. DSAT Obstacles Menu



f. Type the obstacle height and click Add to Map to designate each obstacle with a pin. (***NOTE:*** In general, it is best to use the height at the top of the obstruction, such as the roof peak height for a typical house). When the obstacle-identification pin displays, move it to the precise location of the obstacle that it represents.

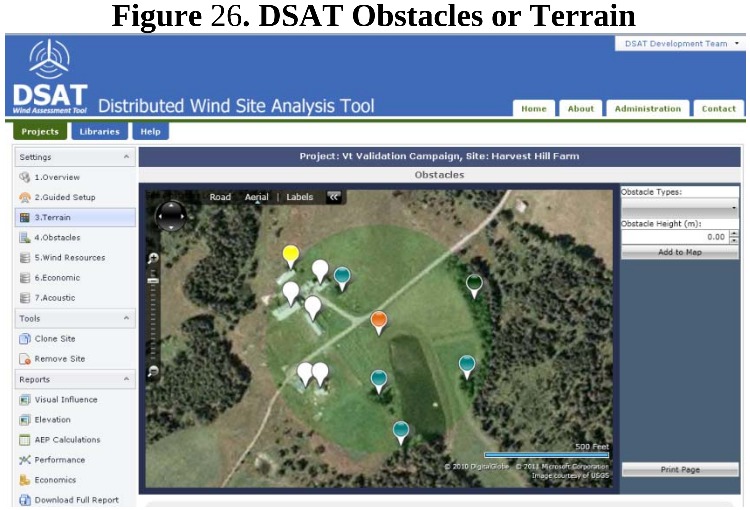
NOTES: Find the dimensions of the obstacles in the Obstacle Library, accessed by clicking the Libraries tab. Choose the listed obstacle that best fits what you have on the site. For example, the purple pin in Figure 25 represents a building, and the green pin represents an evergreen windbreak. The height of the obstacle can be changed either in the menu (to the right in Figure 25) or in the Obstacle Verification field (Figure 27).

Figure 25. DSAT Obstacles Placement



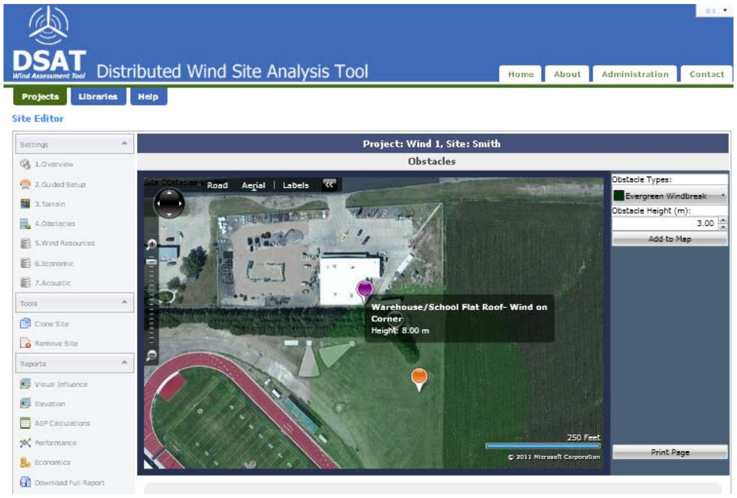
In Figure 26, the obstacles to the east are trees that are part of a larger forest. We recommend treating this as a dense forest terrain rather than individual trees.

Figure 26. DSAT Obstacles or Terrain



g. To display the type of obstacle represented by a particular pin Figure 27, hover your cursor over the pin. You can modify the obstacle type and height from this window by double-clicking on the black information box.

Figure 27. DSAT Obstacle Verification



Understanding the Difference Between Obstacles and Terrains

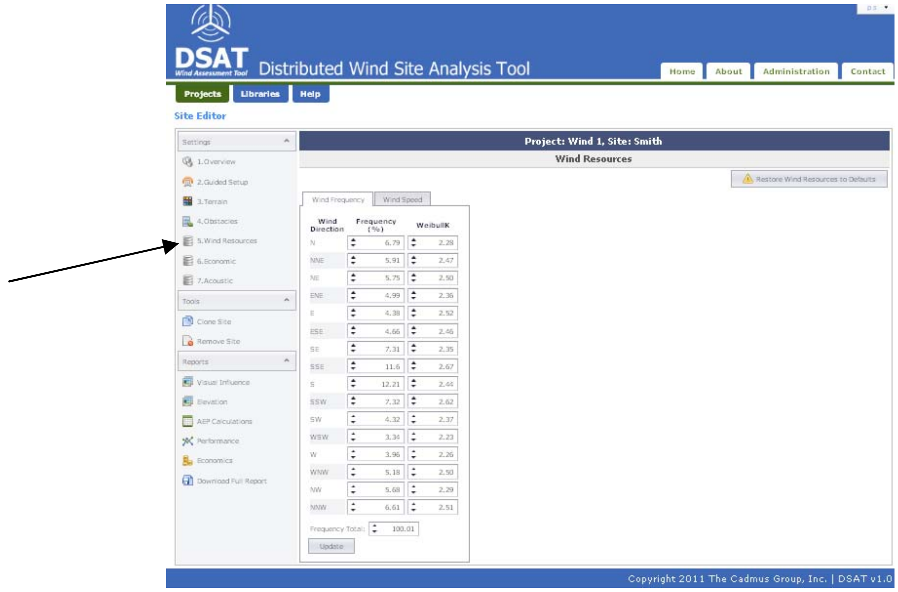
The DSAT interface allows the user a lot of flexibility in defining site characteristics. Determining the difference between an obstruction and a terrain can be confusing to new users but most questions can be resolved by following these general guidelines:

- ***How many obstructions are there?*** Three or fewer obstructions in a direction will generally be best modeled as individual obstructions. More than three obstructions may be better modeled as a terrain type
- ***How much area is covered by the obstruction(s)***? Check the satellite map. If more than 50% of the area in a direction is covered by trees, buildings, or other obstructions, the sector will be better modeled as a terrain type.
- ***What if a sector contains multiple terrain types?*** If, for example, a site is located in a clearing surrounded by forest, the terrain around the turbine is best modeled using the more conservative of the available terrain choices. In Figure 26, the eastern sectors are modeled as sparse forest terrain to reflect the presence of forest near the edge of the area of interest.

Step 7. Specify Wind Resources

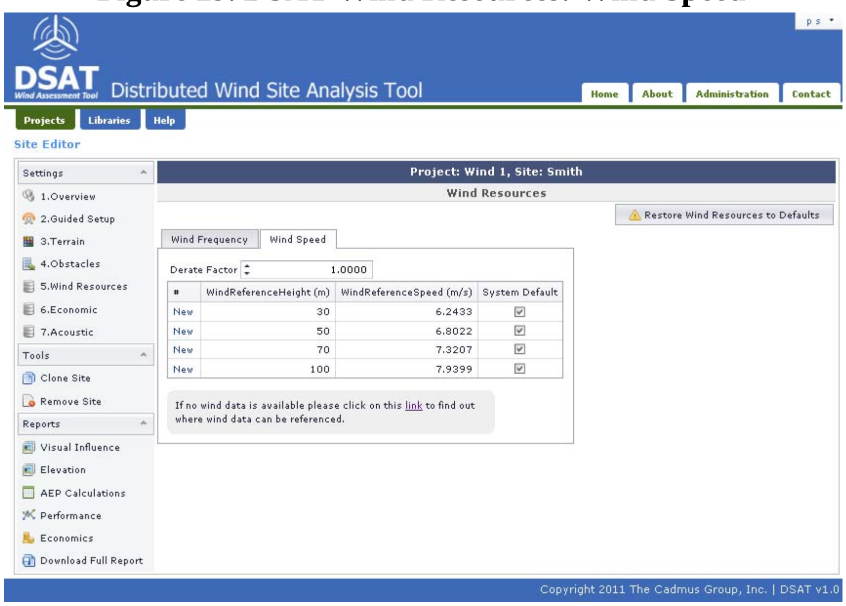
a. Click Wind Resources in the left pane to view the site's wind data.

Figure 28. DSAT Wind Resources: Wind Frequency



NOTE: The site's wind directional frequency (Figure 28) and estimated annual mean wind speed (Figure 29) are displayed on separate tabs. DSAT will automatically populate these fields in most cases. These values may also be manually adjusted. A derate factor can be applied to adjust the wind speed if desired.

Figure 29. DSAT Wind Resources: Wind Speed

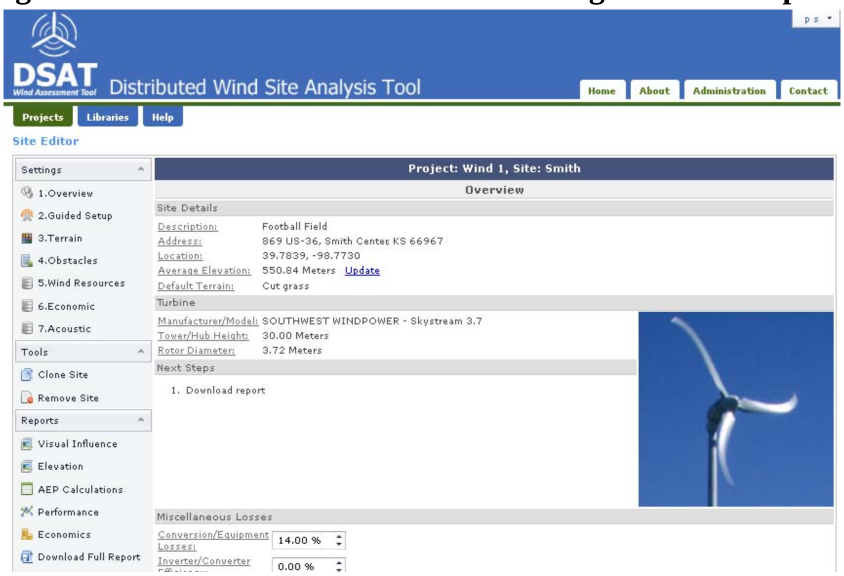


Step 8. Use the DSAT Tools Menu

The menu in the navigation pane on the left side of the screen has three categories: Settings, Tools and Reports (Figure 30). User input is needed for the Settings menu, which sets up the configurations of the projects and sites. The tools available are these:

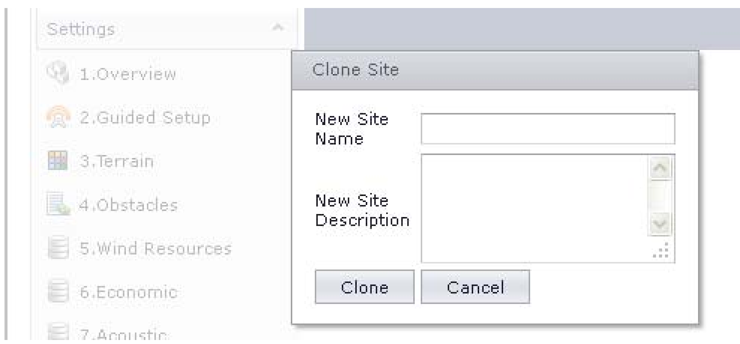
- ***Clone Site.*** Cloning a site allows you to create variations on a site configuration while eliminating the need to create a new site in the Projects tab.) and
- ***Remove Site.*** You can remove a site from the project using this tool or by deleting a site from the Projects tab table.)

Figure 30. DSAT Left Column Menu: Settings - Tools - Reports



It is important to name and describe the clones carefully so that you can easily determine the configuration you wish to view (Figure 31).

Figure 31. DSAT Left Column Menu: Tools – Cloning



Review Visual Influence

The Visual Influence map displays the areas where the proposed wind turbine would and would not be visible. This is It is calculated using a line-of-sight from a point looking toward the turbine (Figure 32). If obstacles or terrain features block the line-of-sight between the turbine and the view location, the turbine would not be visible from that location.

Figure 32. DSAT Visual Influence: Line of Sight

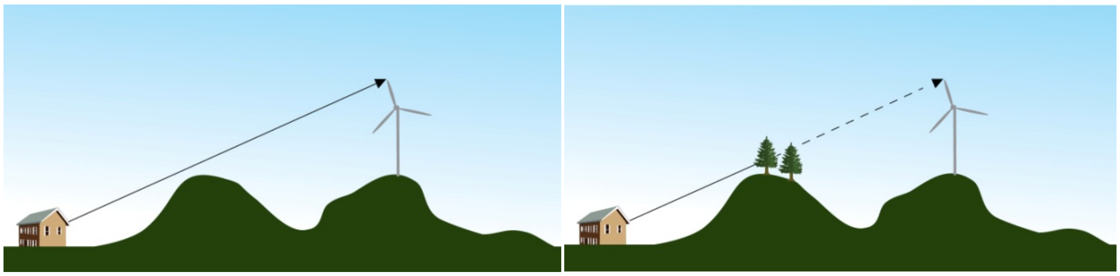
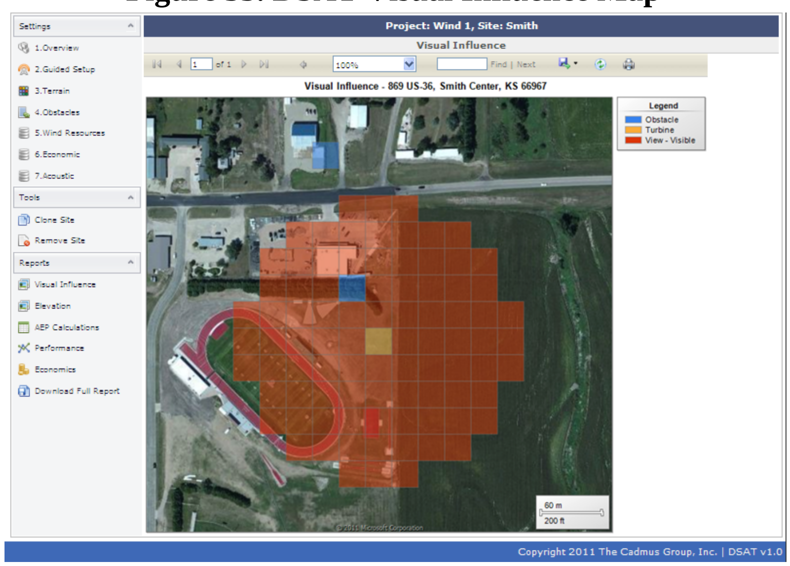


Figure 33 illustrates the result of calculations done at points located within a 20-rotor diameter radius of the proposed turbine location.

Figure 33. DSAT Visual Influence Map



a. When opening DSAT to start a new project or add a site to the existing one, click on the Projects tab..

b. When the Projects List displays (Figure 34), click the small triangle on the left to list the sites in this project.

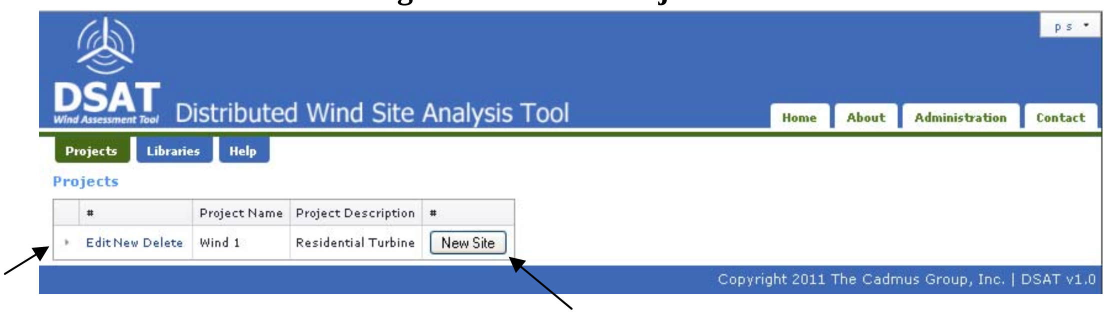
c. To create a new project, click **New** (the link between the Edit and Delete links).

d. To create a new site, click the **New Site** button on the right side of the table.

e. To view or edit existing sites in a project, click on the name in the site column.

f. To add a new site, use the **New Site** button and the site setup configuration will open for the new site.

Figure 34. DSAT Project List



g. Click the Home tab to view the Projects and Sites QuickSearch feature (Figure 35). Type in the Site, Address, Terrain, or Last Update field to find a site on the projects list.

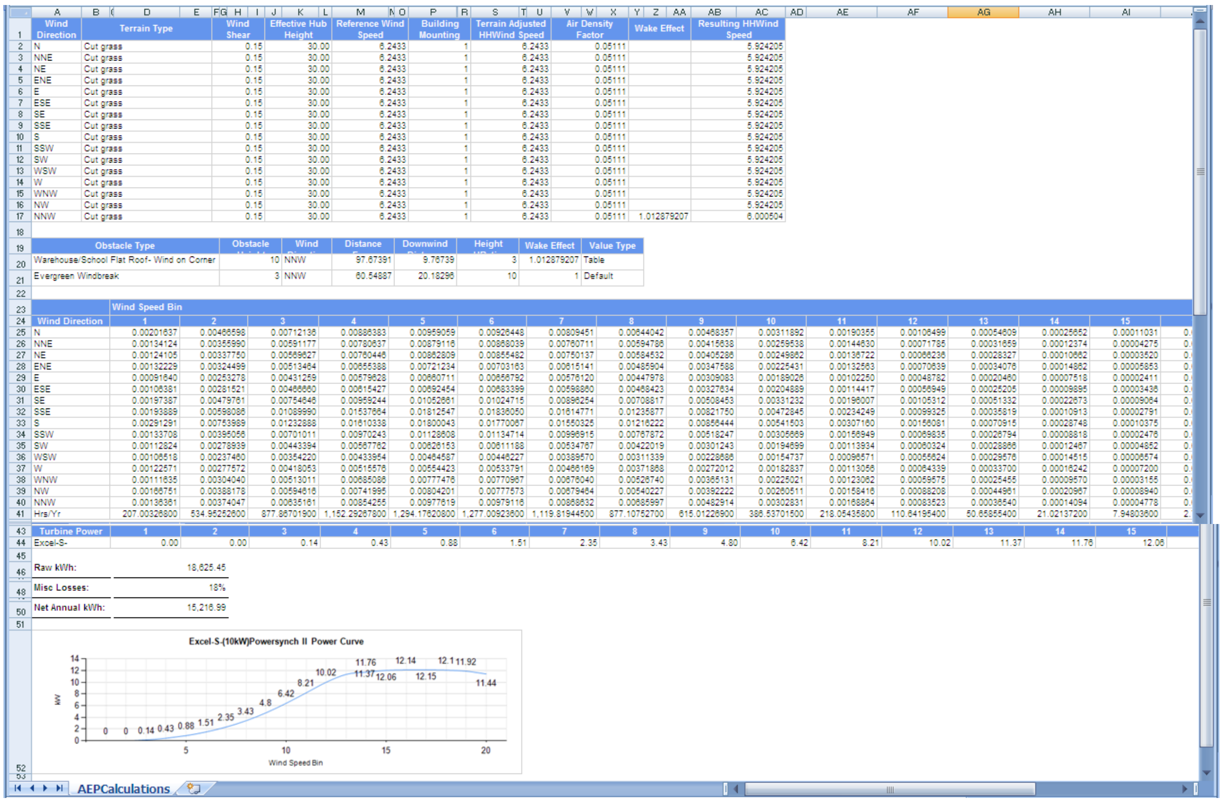
Figure 35. DSAT Projects & Sites QuickSearch

Reports

AEP Calculations Report

The AEP calculations report (Figure 36) is an Excel spreadsheet that shows the terrain types in the sixteen sectors around the turbine, locations of obstacles, directionally binned wind frequencies, gross- and net-annual energy generation, miscellaneous losses, and a graph of the turbine power curve.

Figure 36. DSAT AEP Calculations



Full Report (Site Assessment Report)

The Full Report lists the site's location, physical characteristics, and wind resource statistics. The report also describes the impact of obstructions and terrain variables on wind resources.

The report graphically represents the prevailing wind direction and the site obstruction profile. The wind resource statistics display the estimated Weibull shape factor and wind shear values used to estimated the performance of the chosen wind turbine.

After specifying all parameters for the site, click "Download Full Report" to generate a PDF file that can be downloaded to your local computer. Refer to Figure 37 for a sample of the Full Report.

The Site Summary page presents the following data for the proposed project:

- Turbine location
- Elevation
- Terrain roughness
- Obstruction profile

The Wind Resource page presents:

- Wind speed at reference height
- Weibull k value
- Wind rose table and graph
- Wind speed distribution

The Electricity Generation and Environmental Benefits page presents:

- Turbine manufacturer and model
- Tower configuration
- Miscellaneous losses
- Estimated Annual Energy Production (AEP)
- Turbine power curve
- Potential environmental benefits

The Visual and Sound Impacts page presents

- Visual influence map

Figure 37. DSAT Full Report

Distributed Wind Site Analysis Tool

The Distributed Wind Site Analysis Tool (DSAT) is a powerful online tool for conducting detailed site assessments for single turbine projects, from residential to community scale. DSAT, created by a partnership between The Cadmus Group, Inc., Encraft, and the National Renewable Energy Laboratory (NREL), is made possible through funds from the U.S. Department of Energy.

Aerial View

Report Date: 11/6/2011

Report Author:	
Company:	Cadmus Group, Inc.
Author Email:	
Prepared For:	
Project Name:	Wind 1
Site Name:	Smith
Proposed Site Address:	869 US-36, Smith Center, KS 66967
Turbine Manuf/Model:	SOUTHWEST WINDPOWER/Skystream 3.7

Disclaimer: This tool was developed by the Cadmus Group Inc. on behalf of the Department of Energy. It is intended to provide a coarse estimate of wind resource and no guarantee is made as to the actual resource availability for specific locations. Users enter site condition parameters such as terrain and obstacles and other variables that affect the model's resource estimation. The tool provides a preliminary rough estimate of what the likely wind resource is for the area of interest. If the resource estimate appears sufficient to warrant further consideration please contact a qualified wind turbine installer for a detailed site assessment and system design.

Site Summary

Project Information

Report Date: 11/6/2011

Report Author: Cadmus Group, Inc.

System Owner:

Owner's Email Address:

Proposed Site Address: 869 US-36, Smith Center, KS 66967

Turbine Location (Decimal Degrees)

Latitude: 39.7839 °

Longitude: -98.7730 °

Elevation (m): 557

General Terrain Category: Cut grass

Terrain Roughness, Wind Shear & Porosity

Direction	Terrain Type	Wind Shear Exponent	Canopy Height (m)	Solidity
N	Cut grass	0.15	0.0	0.00
NNE	Cut grass	0.15	0.0	0.00
NE	Cut grass	0.15	0.0	0.00
ENE	Cut grass	0.15	0.0	0.00
E	Cut grass	0.15	0.0	0.00
ESE	Cut grass	0.15	0.0	0.00
SE	Cut grass	0.15	0.0	0.00
SSE	Cut grass	0.15	0.0	0.00
S	Cut grass	0.15	0.0	0.00
SSW	Cut grass	0.15	0.0	0.00
SW	Cut grass	0.15	0.0	0.00
WSW	Cut grass	0.15	0.0	0.00
W	Cut grass	0.15	0.0	0.00
WNW	Cut grass	0.15	0.0	0.00
NW	Cut grass	0.15	0.0	0.00
NNW	Cut grass	0.15	0.0	0.00

10 Most Significant Obstacles at Site

Obstacle Type	Distance to Turbine (m)	Bearing	Obstacle Height (m)
Warehouse/School Flat Roof- Wind on Corner	97.7	338	10.0
Evergreen Windbreak	60.5	338	3.0

Notes

Football Field

Wind Resource

Wind Resource Information

Wind Map Reference Height (m): 30

Wind Map Wind Speed (m/s): 6.24

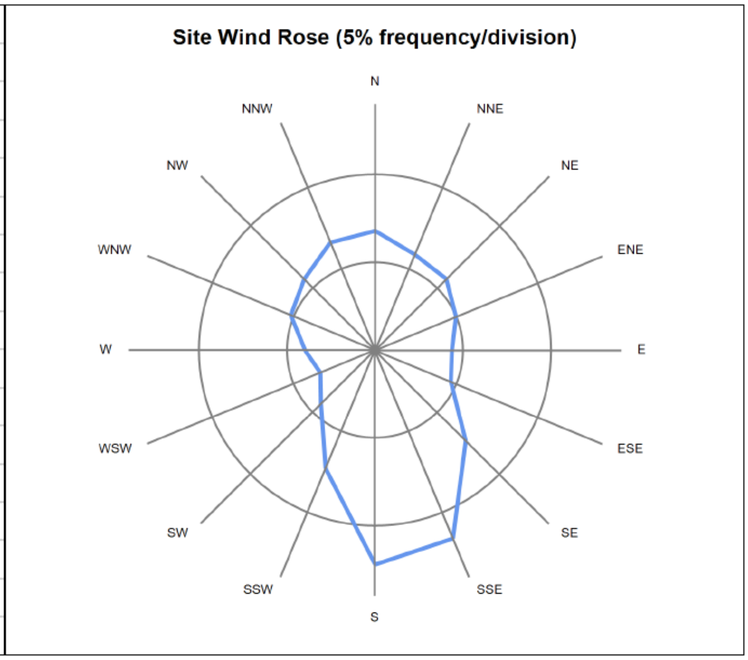
Wind Speed Corrected for Site Factors (m/s): 5.93

Data Source: NREL Data

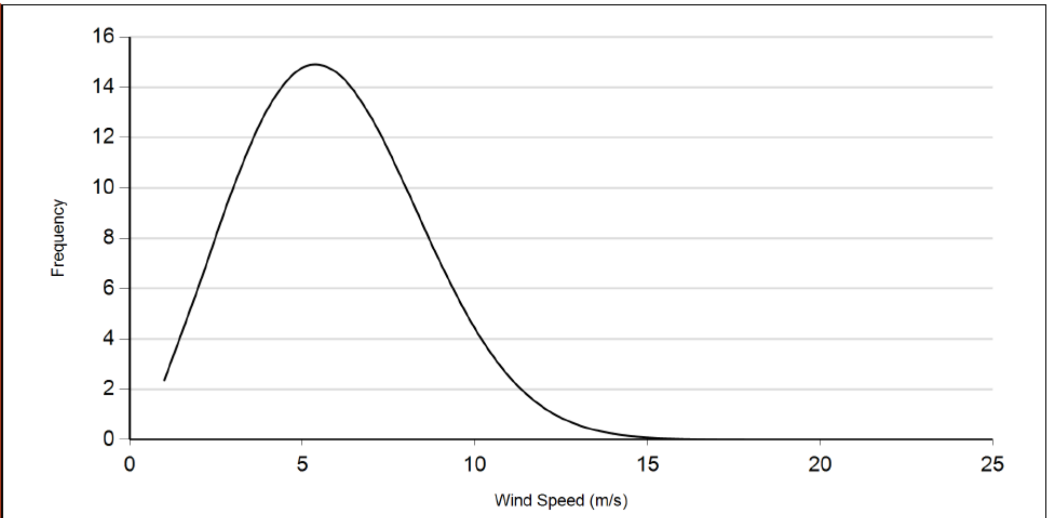
Weibull k Value: 2.43

Site Wind Rose

Direction	Frequency %
N	6.79
NNE	5.91
NE	5.75
ENE	4.99
E	4.38
ESE	4.66
SE	7.31
SSE	11.60
S	12.21
SSW	7.32
SW	4.32
WSW	3.34
W	3.96
WNW	5.18
NW	5.68
NNW	6.61



Projected Annual Wind Speed Distribution



Electricity Generation and Environmental Benefits

Turbine Specifications

Manufacturer:	SOUTHWEST WINDPOWER
Model:	Skystream 3.7
Tower Height(m):	30.00
Mounting Type:	Tower
Rated Power (kW):	2.40
Warranty (yrs):	5

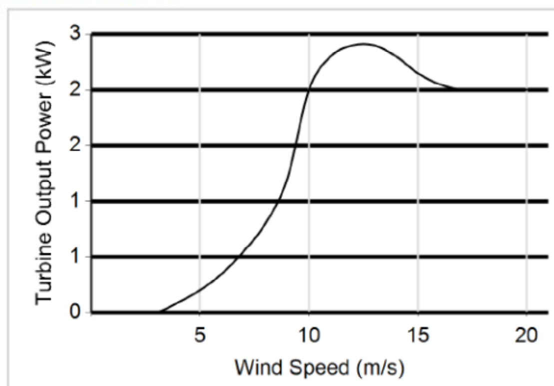
Miscellaneous Losses

Conversion/Equipment Losses:	14.00%
Voltage Drop:	0.00%
Blade Wear/Roughening:	0.00%
Standby Power Draw:	0.00%
Downtime:	5.00%

System Performance Information

Mean Annual Hub Height Wind Speed (m/s):	5.93
Typical Annual Electricity Generation (kWh):	3,758

Power Curve



ENVIRONMENTAL BENEFITS

Annual lb/kg of CO2 (Carbon Dioxide) Emissions Offset:	7,122.04 / 3,230.50
Annual lb/kg of NOx (Nitrogen Oxides) Emissions Offset:	14.75 / 6.69
Annual lb/kg of SO2 (Sulfur Dioxide) Emissions Offset:	22.38 / 10.15
Annual lb/kg of CH4 (Methane) Emissions Offset:	0.09 / 0.04
Annual lb/kg of N2O (Nitrous Oxide) Emissions Offset:	0.12 / 0.05
Annual lb/kg of Hg (Mercury) Emissions Offset:	0.00 / 0.00
Equivalent Acres of Trees Planted:	0.69
Equivalent Cars Taken Off Road:	0.63

Visual Impacts

Distributed wind energy projects, in some cases, may raise concerns related to visual and acoustic impacts. To help identify potential issues with project sites, DSAT combines site characteristics; such as terrain, elevation, and obstructions with turbine performance data to estimate potential visual and acoustic impacts of the proposed project. The data presented in this report is limited by the accuracy of the information provided by the user and should be used for informational purposes only.

Visual Impact of Turbine in Surrounding Area

Map of Zone of Visual Influence

This graphic is known as a "Zone of Visual Influence" (ZVI) graph. By combining elevation, terrain, and obstruction data, DSAT performs a line of sight calculation to determine at which locations the turbine will be visible. Obstructions, such as tall buildings or trees, will likely obstruct the view of the turbine from some areas and this graphic can be used to address visibility concerns for neighbors and communities. If the ZVI graphic shows that a turbine will be visible from a sensitive location, Cadmus recommends that a further analysis, such as a photosimulation be performed to verify any potential impacts

Section 2. Site Assessment

This section offers a list of typical site assessment activities recommended for residential to utility-scale wind installations. This guide addresses aspects in detail that pertain to using DSAT (appearing in **bold**).

Typical Site Assessment Activities

A site assessment typically consists of the following activities:

1. Quantify total electrical use and load profile at candidate site(s).
2. Identify the most favorable site(s) that meet recommended wind resource requirements.
3. For selected site(s), identify the most suitable locations based on terrain, obstacles, zoning and setback requirements, interconnection length, and other potential impacts.
4. Document the height and location of obstacles and their potential impacts on the wind resource.
5. Determine the minimum acceptable tower height, considering terrain, obstacles, and wind resource availability.
6. Evaluate the wind resources at the candidate sites. This may include:
    a. Referencing wind resource maps[3]
    b. Installing wind monitoring equipment to evaluate actual site conditions (generally for larger projects)
7. Using data collected in Steps 2 and 3 specify multiple wind turbine system options, including generator and tower height.
8. Using data collected in Step 6, determine the average annual wind speed at the specified tower height for each candidate turbine and location.
9. Estimate the energy production of each system option.
10. Select the most suitable system options based on identified needs.

Performing a Site Assessment

This section contains recommendations for siting a well-performing wind turbine system. To that end, these guidelines may be modified to accommodate unique site variables.

Assessing Wind Resources

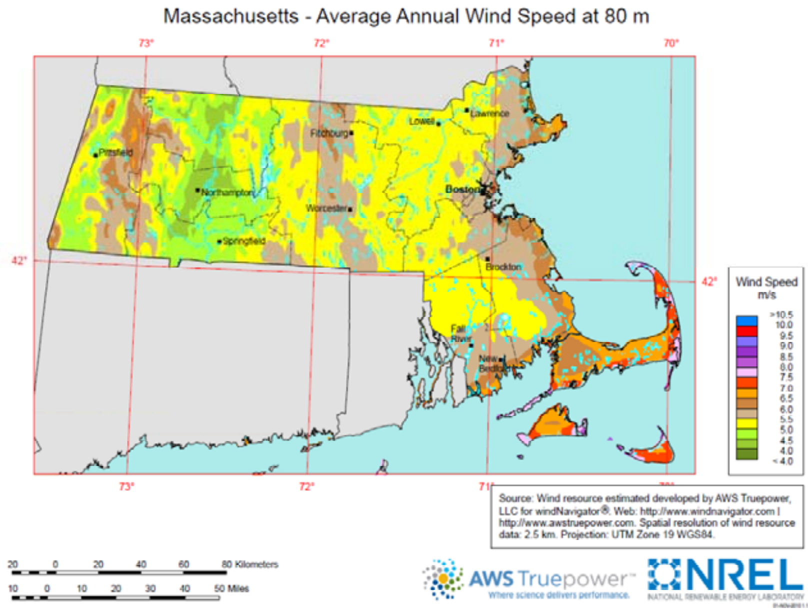
Reference wind resource maps for a preliminary estimate of wind resources at the candidate sites (see Figure 38). DSAT will give an estimate of the wind resources at the chosen location. DSAT will display the following parameters:

- Average annual wind speed

[3] Website links to wind resource maps can be found in the Appendix: Site Assessment Resources.

- Prevailing wind direction (wind rose)
- Wind speed distribution[4]

Figure 38. NREL Validated Wind Resource Map Example



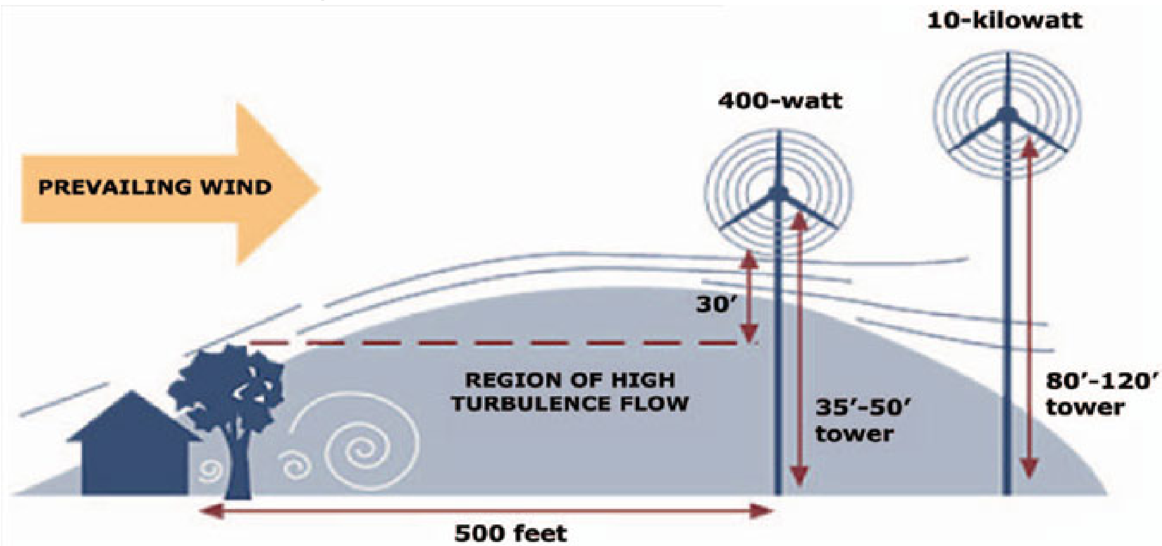
[4] These functions are embedded within DSAT.

Estimating Minimum Hub Height

A minimum annual average wind speed of 4.5 to 5 miles/second (m/s) at hub height is generally needed to support a well-performing system. Typical hub heights range from 60 feet (18 meters) to 120 feet (37 meters).

As shown in Figure 39, obstacle clearance guidelines suggest that the bottom of the turbine's rotor sweep should be sited at least 30 feet above obstacles within 500 feet of the turbine.

Figure 39. Obstacle Clearance Parameters*



* From http://www.smallwindtips.com/tag/tower-height/.

Note: When evaluating or measuring the height of trees or large shrub obstacles, use the *mature* height of obstacle for the siting survey and calculations. Otherwise, subsequent tree growth could obstruct the available wind resource.

Depending on the terrain roughness and obstruction severity, a turbine may require additional clearance beyond the 30-foot minimum. In New England, where groundcover predominately consists of densely wooded forest, hub heights exceeding 100 feet are generally recommended.

Determining Site Coordinates

Verify or document the coordinates for the proposed tower location. This can be accomplished using one of several methods, including hand-held devices, assessors' maps, or free software programs such as Google Earth.

Assessing the General Site Topographic Characteristics

With respect to wind resources, the most favorable turbine location at a given site will typically be at the highest elevation, have the smoothest land cover, and have few obstructions in the direction of the prevailing wind. Western or southwestern exposures are generally desirable inland, whereas turbines sited along the coast can benefit from sea breezes, depending on the location.

The presence of complex terrain or obstructions necessitates careful micro-siting, as different specific locations may experience vastly different wind resources. In general:

- Rough, mountainous terrain is less likely to yield a suitable site than flat or smooth terrain such as rolling hills, agricultural fields, deserts, and bodies of water.
- Obstacles such as trees, hills, and buildings create local wind flow distortion, resulting in turbulent winds.
- Turbulence or eddies reduce the amount of power that most turbines can extract from the wind.

For example, a turbine sited in the wake of a hill would likely have poor performance compared to a turbine installed at the peak of that hill, due to the effects of shading (blockage) and turbulence.

Surveying Candidate Sites for Obstructions and Land Cover

Table 1 lists generic wind shear estimates for six different land cover types. The shear value is used in the power law formula to quantify the roughness impact on the wind resource.

Table 2. DSAT Land Cover Roughness Wind Shear Table

Land Cover Type	DSAT Terrain Roughness Category	Wind Shear Value (α)
a. Ice, open pavement, snow, level beach, water	Ice or pavement	0.08
b. Grass	Cut grass	0.15
c. Agricultural	Cropland/agricultural	0.21
d. Scattered	Scattered trees and hills	0.29
h. Sparse	Sparse forest	0.34
i. Suburban	Scattered buildings and suburban	0.34
j. Dense forest (50-100ft)	Dense forest	0.44
k. Urban	Urban	0.44

Examples of terrain roughness categories are shown in Figure 40.

Figure 40. Examples of Terrain Roughness Categories

The following terrain categories are shown from above:

a. ***Ice or pavement:*** Water, ice or land without vegetation exerts the least friction against the wind.

b. ***Cut grass:*** Grasses create more friction than open water or very flat terrain with no vegetation.

c. ***Cropland/agricultural:*** Crops, fences or shrubs create more friction.

d. ***Scattered hills and trees:*** Scattered trees or hills create resistance and turbulence.

e. ***Sparse forest:*** Sparse trees create resistance but not as much as a dense forest.

f. ***Scattered buildings or suburban:*** Buildings cause some resistance and turbulence.

g. ***Dense forest:*** Dense trees create significant resistance and turbulence.

h. ***Urban:*** Clusters of buildings typical of urban environments present the most friction and turbulence of the locations shown.

Completing an Obstruction Survey

Measure the height and location of obstacles for each of the 16 directional sectors that are within 20 rotor diameters of the base of the proposed tower location.

Note: Several techniques, explained below, are available for surveying the area around the proposed turbine equipment. When used in combination with a compass, these height-measuring methods will improve the accuracy of the site assessment. Print a survey form (shown in Appendix A) or a blank site characteristics page to document your findings while on site.

Shadow Survey Method

a. Drive a stake into the ground near the obstacle.

b. Measure the height of the stake and the length of its shadow.

c. Measure the length of the obstacle's shadow.

d. Use the equation below to determine the height of the obstacle.

$$height\ of\ obstacle = \frac{height\ of\ stake}{length\ of\ stake\ shadow} \times length\ of\ obstacle\ shadow$$

Clipboard Method

a. Look in the direction of the obstacle. Hold a sheet of paper (attached to a clipboard) vertically out in front of you at arm's length. Align the bottom of your clipboard between your eye and the bottom of the obstacle.

b. Mark the clipboard paper where it coincides with the top of the obstacle. Measure the distance between the bottom of the clipboard and the mark.

c. Measure and document the distance between your location and the obstacle

d. Measure and document the length from your eye to the clipboard when your arm is fully extended. Be sure to use the same measuring units as you used for Step b (e.g., inches, centimeters).

e. Calculate the height of the obstacle using the equation below. The results will indicate the same units as you used in Step c (e.g., feet, yards).

$$\boldsymbol{height\ of\ obstacle} = \frac{\boldsymbol{length}\ (\boldsymbol{step\ b})}{\boldsymbol{length}\ (\boldsymbol{step\ d})} \times \boldsymbol{distance}\ (\boldsymbol{step\ c})$$

Rangefinder Survey Method

Use a laser rangefinder with a height measurement option to estimate the height of obstacles at the site. This method is often more accurate and easier to implement than the methods described above.

Use the survey form is provided in Appendix A to facilitate the gathering of information on-site.

Appendix A: Onsite Survey Form

Table A1: Key Information	
Survey Date	mm/dd/yyyy
Name	
System Installer	
Location Address	
Location Coordinates	
Site Elevation	
Proposed Turbine Make/Model (rated power kW)	
Tower Height/Type	
Installer Annual Energy Output Estimate (kWh/yr)	
Anemometer Height	

Figure A1: Site Map of Proposed Wind Project Location

Table A2: Obstructions - type and height of each obstruction with notes							
Direction	@ 1 rotor diameter	@ 2 rotor diameter	@ 3 rotor diameter	@ 4 rotor diameter	@ 5 rotor diameter	@ 6 rotor diameter	@ 7 rotor diameter
N							
NNE							
NE							
ENE							
E							
ESE							
SE							
SSE							
S							
SSW				Row of conifers, 3 m			
SW							
WSW							
W							
WNW							
NW							
NNW							

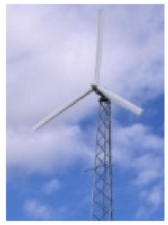
Table A3: Terrains							
Direction	@ 1 rotor diameter	@ 2 rotor diameter	@ 3 rotor diameter	@ 4 rotor diameter	@ 5 rotor diameter	@ 6 rotor diameter	@ 7 rotor diameter
N							
NNE							
NE							
ENE							
E							
ESE							
SE							
SSE							
S							
SSW							
SW							
WSW							
W							
WNW							
NW							
NNW							

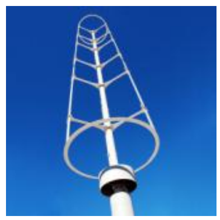
Suggested onsite photos: Obstructions within 20 rotor diameters of the wind turbine

Appendix B: DSAT Libraries

Table B1: Wind Turbine Library

Manufacturer	Model	Image	Commonly Available Hub Heights	Rated KW	Rated Capacity Wind Speed
Bergey Windpower Co.	Excel-S-(10kW)Powersynch II Photo courtesy of Bergey Windpower		18, 24, 30, 37, and 43m	8.21	11.00
Endurance Wind Power, Inc.	E-3120		30.6, 36.4,42.4, 31.5, 43.7m	50.00	11.00
Northern Power Systems	Northern Power 100		30, 37m	100	14.00
Xzeres Wind (formally Abundant Renewable Energy's ARE 110)	ARE 110			2.5	11.00
Xzeres Wind (formally Abundant Renewable Energy's ARE 442)	ARE 442			10	11.00
Gaia-Wind	Gaia Wind 11kW			11	9.50

Endurance Wind Power, Inc.	Endurance S-343			5.2	11.00
Enertech, Inc.	Enertech E13			40	13.4
Proven Energy	Proven 11			5.2	11.00
Proven Energy	Proven 35-2			12.1	11.00
Seaforth Energy	AOC 15/50			50	11.30
Southwest Windpower	Skystream 3.7		18.3m	2.4	12.50
Eoltec	Scirocco E5.5-6 Photo courtesy Eoltec			6	11.50

ReDriven, Inc.	10 kW Photo courtesy ReDriven, Inc.			10	10.00
ReDriven, Inc.	50 kW Photo courtesy ReDriven, Inc.			50	11.00
Mariah Windspire	1.2 kW			1.2	10.70
Vestas RRB	PS-600, 600 kW			600	15.00
Turbowinds	T600-48, 600 kW Photo courtesy Turbowinds			600	12.5
EWT Emergya Wind Technologies	900 kW			900	13.00
Nordic Windpower	1.0 MW		80m	1000	16.00

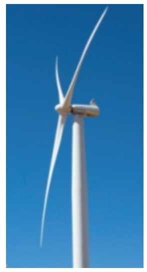
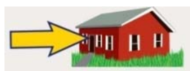
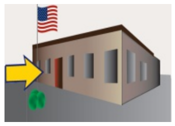
Vestas	V82-1.65 MW Photo courtesy Vestas Wind Systems		70, 80m	1650	13.00
Vestas	VestasV80-2.0 MW Photo courtesy Vestas Wind Systems		67, 80m	2000	16.00
General Electric	1.6MW		80 m	1600	15.00
Suzlon	1.250 MW		75m	1250	14.00
Fuhrlaender	1.5MW Photo courtesy Fuhrlaender North America		61.5, 65, 100, 114.5m	1500	11.0

Table B2: Obstacles Library

Obstacle Name	Image	ID	Roof Pitch	Trunk Height	Height Meters	Width Meters	Length Meters	Skew Angle	Perme-ability
Two Story House Pitched Roof - Wind on Gable End		B	45		6	10	10	0	0
Two Story House Pitched Roof - Wind on Corner		B	45		6	10	10	45	0
Two Story House Pitched Roof - Wind on Broad Side		B	45		6	10	10	90	0
Two Story House Pitched Roof - Wind on Gable End		B	45		10	10	10	0	0
Two Story House Pitched Roof - Wind on Corner		B	45		10	10	10	45	0
Two Story House Pitched Roof - Wind on Broad Side		B	45		10	10	10	90	0
Three Story House Pitched Roof - Wind on Gable End		B	45		12.5	10	10	0	0
Three Story House Pitched Roof- Wind on Corner		B	45		12.5	10	10	45	0
Three Story House Pitched Roof - Wind on Broad Side		B	45		12.5	10	10	90	0
Wide Three Story Pitch Roof - Wind on Gable End		B	45		12.5	15	10	0	0
Wide Three Story House Pitched Roof - Wind on Corner		B	45		12.5	15	10	45	0
Wide Three Story Pitched Roof - Wind on Broad Side		B	45		12.5	15	10	90	0
Warehouse/School Flat Roof - Wind on Narrow Face		B	0		6	100	50	0	0

Warehouse/School Flat Roof - Wind on Corner		B	0		6	100	50	45	0
Warehouse/School Flat Roof - Wind on Wide Face		B	0		6	100	50	90	0
Square Warehouse/ School Flat Roof - Wind on Any Side		B	0		6	50	50	0	0
Square Warehouse/ School Flat Roof - Wind on Corner		B	0		6	50	50	45	0
High Warehouse/School Flat Roof - Wind on Narrow Face		B	0		12	100	50	0	0
High Warehouse/School Flat Roof - Wind on Corner		B	0		12	100	50	45	0
High Warehouse/School Flat Roof Wind on Wide Face		B	0		12	100	50	90	0
High Rise/Large Office - Wind on Narrow Face		B	0		50	20	50	0	0
High Rise/Large Office - Wind on Corner		B	0		50	20	50	45	0
High Rise/Large Office - Wind on Wide Face		B	0		50	20	50	90	0
Square High Rise/Large Office- Wind on Any Side		B	0		50	20	20	0	0
Square High Rise/Large Office - Wind on Corner		B	0		50	20	20	45	0
Deciduous Tree 1 (less porous)		V		4	17.5	14	14	0	

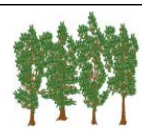
Deciduous Tree 2 (more porous)		**V**		**4**	**17.5**	**12.5**	**12.5**	**0**	
Winter Deciduous Tree		**V**		**4**	**17.5**	**13.5**	**13.5**	**0**	
Evergreen Tree 1 (conifer less porous)		**V**		**2.5**	**17.5**	**9**	**9**	**0**	
Evergreen Tree 2 (conifer more porous)		**V**		**2.5**	**17.5**	**9**	**9**	**0**	
Deciduous Windbreak		**V**		**2.5**	**17.5**	**9**		**0**	
Evergreen Windbreak		**V**		**2.5**	**17.5**	**9**		**0**	
Rounded Conical Hill		**T**	**30**		**14.43**	**50**	**50**	**0**	**0**

Table B3: Terrain Library

Terrain Name	Description	Wind Shear Exponent	Solidity	Default Height In Meters
Ice or pavement	Water, ice or pavement	0.08	0	0
Cut grass	grass	0.15	0	0
Cropland/agricultural	agricultural	0.21	0	0
Scattered trees and hills	scattered	0.29	0	0
Sparse forest	sparse	0.34	0.56	10
Scattered buildings or suburban	suburban	0.34	0.76	5
Dense forest	dense	0.44	0.66	10
Urban	urban	0.44	1	20

Appendix C: Additional Resources

The following publications and Websites provide further insight into performance and siting issues related to small wind turbine systems.

AWEA Siting Handbook (Online)
http://www.awea.org/sitinghandbook/download_center.html

AWS Truepower
https://www.windnavigator.com/cms/login-page

Chiras, D., Sagrillo, M., and Woofenden, I. *Power from the Wind: Achieving Energy Independence by Dan Chiras*. New Society Publishers. 2009.

DWEA: Selecting a Wind Turbine Site
http://guidedtour.windpower.org/en/tour/wres/siting.htm

Gipe, Paul. *Wind Power: Renewable Energy for the Home, Farm and Business*. Chelsea Green Publishing Company. 2004.

NREL-Validated State Wind Resource Maps
http://www.windpoweringamerica.gov/wind_maps.asp

Small Wind Tips
http://www.smallwindtips.com/

DSIRE
http://www.dsireusa.org/

Small Wind Certification Council
http://www.smallwindcertification.org/

APPENDIX B: DSAT ACCURACY OVERVIEW

How Accurate is DSAT?

In order to calibrate DSAT's predictions to improve accuracy, Cadmus collected electrical energy generation and site characteristic data for 65 sites, representing a diverse range of geographic locations, turbines, and terrain types. Cadmus screened the data for completeness, equipment problems, and accuracy. After removing sites with insufficient or inaccurate data and sites with equipment problems, the final sample included 39 sites.

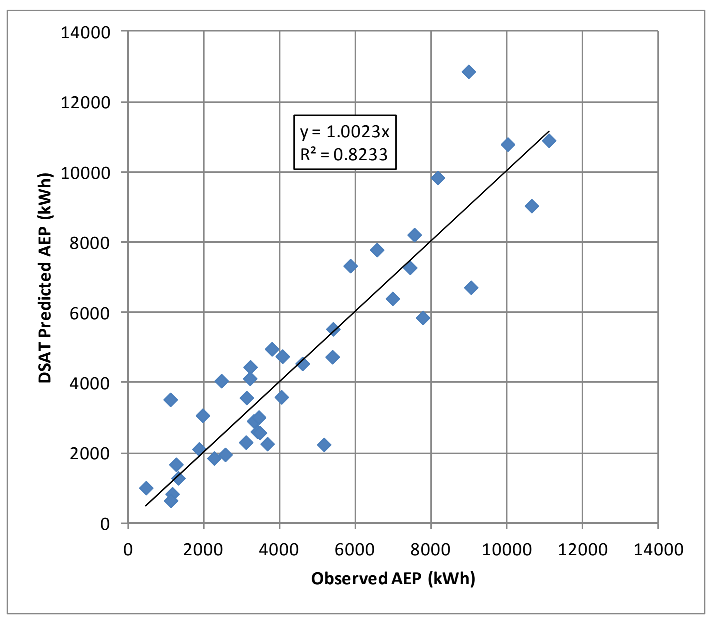
Region	Sites in Sample (n=39)
Massachusetts	21
Vermont	8
California	5
Midwestern States (Wind for Schools)	5

Using a combination of site visits and remote satellite imagery, Cadmus modeled each site in DSAT and calculated the typical annual electrical energy generation and compared this result with the observed energy yield for each site. In order to account for annual variability in wind speed at these 39 sites, Cadmus used long-term weather station data to adjust DSAT's wind speed input to match the wind pattern during the performance period of each wind system.

Turbine Model	Number in Sample (n=39)
ARE 442	1
Endurance S-250	2
Endurance S-343	1
Excel-S Gridtek-10	22
Excel-S-(10kW) Powersynch II	5
Scirocco E5.5-6	2
Skystream 3.7	6

Based on this data, Cadmus examined the model's performance by region, turbine type, and terrain type to identify possible bias in the predictions. After adjusting regional wind resource data based on these results, Cadmus estimated the accuracy of DSAT's predictions.

For the sample population, DSAT predicts overall energy yield with an accuracy of within 2%. DSAT predicts the energy output of individual systems with an accuracy of +/- 28%. This accuracy is driven primarily by uncertainty in wind resource data.



There is no significant bias between actual energy yield and model predictions, with minimal deviation of actual results

The results of this are remarkable in addressing a longstanding challenge for the distributed wind energy industry. Cadmus' previous work with small wind programs in the northeast has demonstrated that commonly available tools and techniques for estimate the energy output of small wind turbines can be highly inaccurate. For example, in late 2008, Cadmus found that the energy yield of small wind turbines was over-predicted by nearly 300%. Most other available tools are not calibrated to real sites and do not report the accuracy of their predictions. With DSAT, users can make informed decisions about their potential wind projects, knowing that their predictions are based on real data and a calibrated model.