China Wind Energy Resource Mapping Activity

Introduction

This document describes the development of detailed high-resolution (1 km^2) wind energy resource maps for specific regions of eastern China. These maps were created at the United States Department of Energy's National Renewable Energy Laboratory (NREL) as part of the Solar and Wind Energy Resource Assessment (SWERA) project for the United Nations Environment Programme. The wind mapping activity covered vast areas of eastern China totaling about 2.7 million km^2 of land area and more than 3 million km^2 including offshore areas. These areas included much of Inner Mongolia, northeastern China, coastal and offshore areas of northern, central, and southern China, Hainan Island, and the Poyang Lake and Three Gorges areas of south-central China. For presentation of the maps and discussion of the wind resource, we divided the areas mapped into 15 regions. The maps can be found in a separate part of the SWERA archive.

NREL's Wind Resource Assessment and Mapping System (WRAMS) is a combination of analytical, numerical, and empirical methods using Geographic Information System (GIS) mapping tools and data sets. In the sections below, we discuss the data sets, analysis methods, and mapping system used by NREL to perform the China wind mapping activity. We also present the results of the wind resource assessment, highlighting the major wind resource areas identified and providing confirmation of the resource estimates with available measurement data. Finally, we present estimates of the wind electric potential for the mapped land areas of China and each province.

Meteorological Data

Introduction

An accurate wind resource assessment depends on the quantity and quality of the available meteorological data. NREL reviews many sources of wind data and previous wind assessments as part of its overall evaluation. Several global data sets maintained at NREL, including surface and upper-air observations spanning many years of record, were used in this assessment. These data were supplemented with information from sources in China that included data from wind measurement towers installed for assessing the wind resource.

Because the quality of data in any particular data set can vary, and high-quality data can be quite sparse in many regions, multiple data sets are used. Each data set plays an integral role in the overall assessment.

Surface Data

High quality surface wind data from well-exposed locations can provide the best indication of the magnitude and distribution of the wind resource in the region. Studies by NREL and others in many different regions of the world have found that the quality of surface wind data from meteorological stations varies and is often unreliable for wind resource assessment purposes.

The following sections present a summary of the surface data sets obtained and examined in the assessment.

DATSAV2 Data

The DATSAV2 global climatic database obtained from the U.S. National Climatic Data Center (NCDC) contains the surface weather observations, transmitted via the Global Telecommunications System (GTS), from first-order meteorological stations throughout the world. Meteorological parameters such as wind speed, wind direction, temperature, pressure and altimeter setting are used to create statistical summaries of wind characteristics. A unique six-digit number based on the World Meteorological Organization (WMO) numbering system identifies each station in the DATSAV2 data set.

NREL processed over 500 stations from the DATSAV2 data set for initial examination and used 170 of these stations in its meteorological evaluation and validation of the numerical model data. These stations were largely from China but also included some stations from other countries that were located near the borders with China. The number of observations at the individual stations for each year and from year to year is highly variable. The stations in China typically recorded data every 3 hours, though a few airport locations recorded hourly data.

The processed data records from the DATSAV2 data contained monthly and annual averages of wind speed and wind power. These data are useful for evaluating the interannual and monthly variability, and the diurnal distribution of wind speed and wind power, plus the joint frequency of wind speed and direction.

United Nations Development Programme (UNDP) Data

NREL received tower measurement data for 10 regions in China from China Hydropower Engineering Consulting Group Corporation (CHECC). The UNDP supported the data collection effort that began in late 2002. NREL received data from these towers through mid-2004. There was one 70 m tower in each region supplemented by two or three nearby 40 m towers. Anemometers were installed at the 10, 25, 40, 50, 60, and 70 m levels for the tall towers. The 40 m towers generally had anemometers installed at 10, 25, and 39 m.

Proprietary Data

NREL also received through its Chinese partners proprietary data taken by various wind developers. Around 30 proprietary sites were used in the mapping effort. The data were measured during the 1990s and 2000s.

Other Data Sets from China

Data from several measurement stations used in previous NREL wind resource assessment work in China were also used in the mapping process. The stations included those established in 1998 as part of the China Hydropower Planning General Institute's measurement program in southeast China and proprietary measurements taken during the 1990s on Nanao Island in Guangdong Province.

Upper-air Data

NREL's in-house data sets include both observational and computer model-derived upper-air information. The following upper-air data sets were used for this mapping project.

Automated Data Processing (ADP) Data

The ADP upper-air database consists of information obtained from surface-launched meteorological instrument packages. These packages are launched via balloon once or twice daily and are managed under WMO guidance and procedures. However, the ADP data from weather balloons launched in China were not as detailed as the weather balloon data from other parts of the world, and critical information on the vertical profile of wind speed and power could not be extracted from the ADP data. Therefore, NREL depended primarily on the reanalysis data set, described below, for its analysis of the upper-air data.

Reanalysis Data

The U.S. National Centers for Environmental Prediction, in collaboration with U.S. National Center for Atmospheric Research, produced a reanalysis data set. This is a 45-year record of global analyses of atmospheric parameters. This project used a global weather prediction computer model to create worldwide data sets of wind, temperature, and other variables on a global 208-km resolution grid. Reanalysis incorporates all available rawinsonde and pilot balloon data, as well as observations from surface, ship, aircraft, satellites, and other data sources. Reanalysis data over China were produced for four times a day.

Satellite Ocean Wind Data

Measurements and estimates of ocean winds can greatly aid the assessment of the wind resource for the extensive coastal areas and offshore islands of China. NREL examines several types of satellite-based scatterometer estimates of wind data over ocean areas including QuikSCAT, SSM/I, and TMI data sets. These data give estimates of wind speeds 10 m above the ocean surface and provide an excellent overview of the ambient wind conditions in the ocean areas off the coast of China. However, due to inherent uncertainties with the satellite-based estimates, they should be compared with available measurement data wherever possible. With considerable measurement data available from coastal areas and offshore islands and buoys in China, we primarily used the measurement data rather than the satellite data in the China assessment.

Numerical Model Data

AWS Truewind (AWST), of Albany, New York, provided NREL with wind speed and wind power data for China on a 1 km by 1 km grid with data at levels from 30 m to 500 m above ground. Surface roughness and elevation data from its MesoMap system were also provided to NREL. This data set was used as an initial estimate for the distribution of the wind speed and power in China. The section on the wind resource mapping system describes how the numerical model data were generated.

Data Analysis Methodology

Introduction

The following sections describe the WRAMS including the methodology used to analyze and evaluate the meteorological data used for this resource assessment and the mapping system used to generate the resource maps. Both components are crucial for the production of wind resource maps that are accurate enough to stimulate the development of wind energy in the study regions. The goal of WRAMS is to have the final wind resource data accurate to within 10% of annual average wind speed and 20% of annual average wind power for a large majority (80%) of the grid points.

Data Evaluation and Analysis

Initial Approach

The quality of the meteorological input used to generate the final maps depends on understanding the important wind characteristics in the study region such as the interannual, seasonal, and diurnal variability of the wind and the prevailing wind direction. NREL used innovative assessment methods on existing meteorological data sets to develop a conceptual understanding of these key wind characteristics. These data sets, discussed earlier, are maintained at NREL as part of its global archive and are supplemented with data sets obtained from China. NREL's approach depends on the critical analysis of all the available surface and upper-air data for the China mapping regions and the surrounding areas. NREL used a comprehensive data-processing package to convert the data to statistical summaries of the wind characteristics for more than 600 surface stations and numerous upper-air locations. The summaries were used to highlight regional wind characteristics.

Surface Data Evaluation

Years of resource assessment experience at NREL have revealed many problems with the available land-based surface wind data collected at meteorological stations in much of the world. Problems associated with observations taken at the meteorological stations include a lack of information on anemometer height, exposure, hardware, maintenance history, and observational procedures. These problems can cause the quality of observations to be extremely variable. In addition, many areas of the world with good or excellent potential wind resource areas have very little or no meteorological station data to help assess the level of the available wind resource.

NREL takes specific steps in its evaluation and analysis to overcome these problems. Site-specific products were screened for consistency and reasonableness. For example, the interannual wind speeds were evaluated to identify obvious trends in the data or periods of questionable data. Only representative data periods were selected for the assessment. One prominent feature at a number of surface stations in China was a consistent downward trend in the wind speed and power over a substantial period-of-record. Therefore, the representative periods at many stations were the earlier measurement periods (such as the 1950s, 1960s, and 1970s), and not more recent measurement periods. The summarized products were also cross-referenced to select the sites that appeared to have the best exposure to the prevailing wind. These data, in combination with high-quality data from available wind measurement towers, were used to develop an understanding of the wind characteristics of the study region.

Upper-Air Data Evaluation

Upper-air data can be useful in assessing the regional wind resource in several ways. First, upper-air data can be used to estimate the resource at low levels just above the surface. The low-level resource estimation is quite important in areas where surface data is either sparse or not available. Second, upper-air data can be used to approximate vertical profiles of wind speed and power. The vertical profiles are used to extrapolate the level wind resource to elevated terrain features and to identify low-level wind speed maximums that can enhance the wind resource at turbine hub-height.

NREL generated summaries of wind speed and wind power at specific height levels above the surface, as well as monthly and annual average vertical profiles of wind speed and power. One problem that occurs in the evaluation of upper-air data for complex terrain areas is that some locations where the balloons are launched are blocked from the ambient wind flow by high terrain. Using vertical profiles from reanalysis grid points heavily influenced by the “blocked” locations can be misleading because the profiles only represent conditions at the upper-air station and will not apply throughout the region of interest. Therefore, NREL’s analysis of the upper-air data uses vertical profiles that we judge to be representative of the ambient wind flow in a particular region.

Goals of Data Evaluation

The goal of a critical analysis and evaluation of surface and upper-air data is to develop a conceptual model of the physical mechanisms on a regional and local scale that influence the wind flow. When there is conflicting wind characteristic data in an analysis region, the preponderance of meteorological evidence from the region serves as the basis for the conceptual model.

The critical data analysis and the conceptual model are particularly important because a key component of NREL’s wind mapping system requires that empirical adjustments be made to wind power values before the final maps are produced. The conceptual understanding developed by the critical analysis of the available data guides the development of empirical relationships that are the basis of algorithms used to adjust the wind power. This empirical approach depends on an accurate ambient wind profile of the few hundred meters closest to the surface and being able to adjust it down to the surface layer. A prime advantage of this method is that NREL can produce reliable wind resource maps without having high quality surface wind data for the study region.

Wind Resource Mapping System

General Description

NREL’s mapping system uses GIS mapping software. The main GIS software, ArcInfo®, is a powerful and complex package that features a large number of routines for scientific analysis.

The mapping system is divided into three main components: the input data, the wind power adjustments, and the output section that produces the final wind resource maps. These components are described below.

Input Data

The two primary model inputs are digital terrain data and meteorological data. The elevation information consists of Digital Elevation Model (DEM) terrain data that divide the analysis region into individual grid cells, each having its own unique elevation value. The U.S. Geological Survey’s Earth Resource Observing Satellite Data Center produced updated DEMs for most of the world from previously classified U.S. Department of Defense data and other sources. The data sets have a resolution of 1 km^2 and are available for large parts of the world.

The meteorological inputs to the mapping system come in two phases. The first phase provides wind power data for each grid cell obtained via output from a mesoscale numerical model. The second phase, following the data screening process, consists of empirical adjustments to the original wind power value based on NREL’s meteorological analysis and a comparison of the numerical model data to wind measurement data throughout the study regions.

AWST provided to NREL the initial wind power density values for each grid cell in the China mapping regions. AWST used its MesoMap system to calculate the wind power density values. The MesoMap system consists of the MASS (a mesoscale numerical model) and WindMap (a mass conserving wind flow model).

The MASS model simulated weather conditions over regions of eastern China and the surrounding areas for 366 days randomly selected from a 15-year period. The random sampling was stratified so that each month and season was represented equally. Each simulation generates wind and other meteorological variables throughout the model domain for a particular day and stores the information at hourly intervals. The simulations use a variety of meteorological and geophysical data. MASS uses climatic data to establish the initial conditions for each simulation as well as lateral boundary conditions for the model. The model determines the evolution of atmospheric conditions within the study region during each simulation.

The main geophysical inputs into MASS are elevation, land cover, greenness of vegetation, and soil moisture. The MASS translates both land cover and vegetation greenness into important surface parameters such as surface roughness.

The MASS was run with a horizontal resolution of 2.5 km. After all the simulations were completed, the results were processed into summary data files that were input into the WindMap model. WindMap then calculated the wind power density down to the final 1 km by 1 km grid cell resolution.

The empirical wind power adjustment modules in NREL's wind mapping system use different routines depending on the results of NREL's data evaluation and validation. Power adjustment factors can be initialized to account for terrain features that accelerate or block the flow; the relative elevation of particular terrain features; proximity to lakes, oceans, or other large water bodies; or any combination of the above.

Mapping Products

Wind Power Maps and Classifications

The primary output of the mapping system is a color-coded wind power map in units of W/m^2 (wind power density) and equivalent mean wind speed for each individual grid cell. Wind power density is a better indicator of the available resource because it incorporates the combined effects of the wind speed frequency distribution, the dependence of the wind power on air density, and the cube of the wind speed. The final wind power values for China are estimates that account for NREL's empirical adjustments (where necessary) and the surface roughness of each grid cell derived from the MASS model output.

Seven wind power classifications, based on ranges of wind power density, were used for the China maps. Each of the classifications was qualitatively defined for utility-scale applications (poor to excellent). In general, locations with an annual average wind resource greater than 400 W/m^2 (or about 7.0 m/s) at 50 m above ground are the most suitable for utility-scale applications.

Additional Mapping Products

The mapping system output uses software to produce the proper map projection for the study region, and to label the map with useful information such as a legend, latitude and longitude lines, locations of meteorological and other wind measurement stations, important cities, and a distance scale. The DEM data can also be used to create a color-coded elevation map, a hill-shaded relief map, and a map of the elevation contours. When combined with the wind power maps, these products provide the user with a three-dimensional image of the distribution of the wind power in the analysis region.

Limitations of Mapping Technique

There are several limitations to the mapping technique, the first of which is the resolution of the DEM terrain data. Significant terrain variations can occur within the DEM's 1 km^2 area; thus, the wind resource estimate for a particular grid cell may not apply to all areas within the cell. A second potential problem lies with the extrapolation of the conceptual model of the wind flow to the analysis region. Many complexities in the wind flow exist that make this an inexact methodology. The complexities include the structure of low-level jets and their interaction with the boundary layer; localized circulations, such as land-sea breezes, and mountain-valley flows; and channeling effects in areas of steeply sloping terrain. Finally, the power estimates in China are based on each grid cell's surface roughness based on the MASS output. Because the geophysical input to MASS is not 100% accurate, there can be errors in the surface roughness estimate and consequently the level of wind resource for particular locations in China.

Analysis and Mapping Results

This section describes the results of the evaluation of data from wind measurement locations, the validation and adjustment of the numerical model estimates, and the final wind resource estimates including their confirmation with available measurement data.

Evaluation of Wind Measurement Data

Considerable high-quality wind data from more than 60 wind measurement towers, including ten 70-m towers, were quite valuable in developing more accurate wind resource maps than would have been otherwise possible. All but one of the 15 mapped regions of China had at least one wind measurement tower. The tower data were available from coastal areas of northern, central, and southern China, plains and ridges in northern and northeastern China, wind corridor areas in northeastern China and southern China, and ridges in southern China. Many of the measurement towers were located in areas of good-to-excellent wind resource. However, limitations with these measurement data and the resulting uncertainties need to be recognized to appropriately apply the data in the validation process. Uncertainties result from short periods of data collection, and possible effects of tower structures and mounting booms on measurement accuracy. Only about one year of data was available for many of the measurement sites. Yearly wind speeds can vary up to 10% or more from the long-term means, and yearly wind power densities can vary up to 30% or more from the long-term means. We did not attempt to evaluate if an individual year (or period of measurement) may be a typical, low, or high wind year. Tower shadow effects and mounting booms can cause reductions in the measured wind speeds, but these reductions are not easily quantified.

We processed the observation data from more than 500 meteorological stations to evaluate the wind characteristics in eastern China mapping regions. Unusual or downward trends were observed in the yearly wind speed and wind power density at many stations. These trends could be caused by one or more factors such as new construction or obstacles around the station that reduce the measured wind speeds. We identified 170 stations, predominately from windier areas, for comprehensive analysis in the validation process. These station data were re-processed and analyzed for selected periods of record judged to have the highest quality wind data. Meteorological station data used in the validation were available from offshore islands, buoys and exposed coastal stations, mountain summits and ridges, plateaus and plains, and several wind corridors. Major limitations of the meteorological station data in the validation process include lack of information on the exposure of the wind measurement equipment and the variation of the wind resource with height (wind shear) to extrapolate the wind resource up to the 50-m height. A major advantage of the meteorological station data was the long period of selected data (several years or more) at many of the stations used in the validation. From 10 to 30 years of data were used at some stations.

Validation and Adjustment of Numerical Model Data

NREL compared the numerical model data for China to its estimates of the wind resource based on the intensive analysis of other data sets described above. These validation results were then used by NREL to identify regions where its analytical and empirical methods would be applied in revising the estimates from the numerical model data. These revisions resulted in substantial adjustments to the wind resource in many areas including those noted below. However, in many other areas the numerical model estimates remained unchanged.

The major adjustments, noted by + symbol for substantial increases and – symbol for substantial decreases, are summarized below by region. Most of the adjustments were increases.

Northeastern (Regions 1, 2, & 3)

+ Songhua Jiang wind corridor area located between Harbin and Jiamusi, in Heilongjiang province

Northern (Regions 4, 5, & 6)

+ Inner Mongolia areas north of Baotou and Hohhot from about 107 degrees to 114 degrees longitude
+ Areas of northeastern Hebei Province, particularly ridges and elevated terrain features
– Southern areas of Da Hinggan Ling, from about 43 degrees to 45 degrees latitude, in Inner Mongolia

Northern Coast (Regions 7, 8, & 9)

+ Areas of Liaoing Province, including central areas from Jinzhou northward to about 43 degrees latitude, ridges and elevated terrain features in eastern areas and Liaodong Peninsula, and coastal areas and offshore islands of Liaodong Peninsula
+ Coastal and offshore areas of western and southern Bo Hai
+ Coastal and offshore areas of Yellow Sea from about Qingdao southward to north of Shanghai

Southeastern Coast (Regions 12 & 14)

+ Coastal and offshore areas in Zhejiang and Fujian Provinces
+ Ridge crests and elevated terrain features in Zhejiang and Fujian Provinces

Southern Coast and Hainan (Regions 13 & 15)

+ Coastal areas and offshore areas of central Guangdong Province, from about Hong Kong westward to about Yangjiang
+ Ridge crests and elevated terrain features in southern and central areas of Guangdong Province
+ Western and northern coastal areas of Hainan Province
+ Ridge crests and elevated terrain features in Hainan Province

South Central (Regions 10 & 11)

+ Poyang Lake wind corridor area in northern Jiangxi Province

+ Ridge crests and elevated terrain features in regions 10 & 11

Regional Summaries of Wind Resource and Confirmation of Final Estimates

Northeastern (Regions 1, 2, & 3)

A prominent wind resource feature in Heilongjiang province is the Songhua Jiang wind corridor located between Harbin and Jiamusi. This corridor extends for about 200 km in generally an east-west direction. The excellent wind resource (class 5+) in the western part of the corridor is confirmed by a measurement tower near Mulan. The good wind resource (class 4) in the eastern part of the wind corridor is confirmed by 10 years of data from the meteorological station at Yilan. Terrain features in the eastern part of the corridor with good exposure the prevailing winds are estimated to have excellent wind resource.

The map shows many areas of good-to-excellent wind resource on elevated terrain features in southeastern Heilongjiang. Data from a measurement tower near Muling confirms the excellent wind resource shown for exposed terrain features in that area.

The class 2-3 estimates for the plains of northwestern Jilin and southwestern Heilongjiang are confirmed by data from meteorological stations and measurement towers. Some of tower measurement data indicate that the class 3 resource may be more prevalent in extreme northwestern Jilin than indicated by the map, but the tower data are from just one year.

For region 1 (northeastern parts of Inner Mongolia), the map shows many areas of good-to-excellent wind resource. The best areas are elevated plains and ridges of Da Hingan Ling, around 45 to 46 degrees latitude, but no measurement data were available from these areas. The meteorological stations are located in the lower plains and basins and generally confirmed the class 2-3 estimates shown on the map for these areas. However, data from Xin Barag Youqi meteorological station near Hulun Nur indicated class 4 wind resource.

Northern (Regions 4, 5, & 6)

For region 4 (primarily western parts of Inner Mongolia), the map shows the best wind resource on elevated terrain areas and the northern plains near the Mongolia border. The good wind resource near the Mongolia border is confirmed by data from meteorological stations in those areas including Mandal and Hails. The meteorological stations in the lower plains and basins of this region confirm the class 1-2 resource indicated by the map. The map shows many elevated terrain areas such as Lang Shan, Yin Shan, and Helan Shan where good-to-excellent wind resource is estimated. Data from measurement towers near the southern end of Helan Shan indicate class 3 in class 4 areas on the map; however, only about one year of data were available.

For region 5 (primarily central parts of Inner Mongolia and northwestern Hebei), the map shows major areas of good-to-excellent wind resource in an east-west band primarily between about 41 and 43 degrees latitude. The best areas are generally located on higher plains and elevated terrain. Data from most of the meteorological stations in this high wind belt indicated class 4-5 wind resource. These stations included Jurh, Huade, Shara Moron Sume, Bailingmiao, and Mandal. Jurh measured the highest wind resource. Meteorological stations north of about 43 degrees latitude generally confirmed the class 2-3 wind resource areas shown on the map. Wind measurement towers in the Huitengxile area (located on a plateau east of Hohhot) indicate class 4 resource in areas estimated on the map to have class 4-5, although only about one year of data were available. One year of measurement data from several towers in the

Shangyi area of northwestern Hebei province indicate largely class 3 wind resource in areas estimated to have class 3-4 on the map. Data from wind measurement towers located in exposed areas near Zhangbei in northwestern Hebei confirm the class 5-6 resource estimates on the map for those areas.

For region 6 (primarily eastern parts of Inner Mongolia and northeastern Hebei), the map shows many areas of excellent wind resource particularly the elevated terrain areas in Inner Mongolia and northeastern Hebei. Data from measurement towers at two sites in northeastern Hebei (Chengde Hongsong and Saihanba) confirm the excellent wind resource. The map also indicates areas of good-to-excellent wind resource on the hills and ridges in the region between Chifeng and the Bo Hai coast, but no measurement data were available to confirm these estimates. Data from meteorological stations and one UNDP measurement tower (Chifeng Dali) confirm the class 2-3 map estimates shown for much of the lower and higher plains in this region of Inner Mongolia. No data were available from the class 4+ areas shown in the high plains.

Northern Coast (Regions 7, 8, & 9)

For region 8 (primarily Liaoning province), the map shows many coastal and offshore areas of good-to-excellent wind resource. Data from measurement towers and meteorological stations confirm the good-to-excellent resource for coastal and island locations around Liaodong Peninsula. Coastal measurement locations indicating good resource included towers installed at Dalian Hengshan and Dongli and the meteorological station at Dalian. The excellent offshore resource is verified by a measurement tower on Changhai Island and the meteorological station on Haiyang Island. The class 2-3 estimates for the river plain of Liao He are confirmed by data from meteorological stations in this region. The map shows areas of good-to-excellent wind resource on the many of the hills and ridges of Liaodong Peninsula and southeastern Liaoning, but no measurement data were available to confirm these estimates.

For region 7 (primarily the region to the west of and around Bo Hai), the map shows generally moderate-to-good wind resource (class 3-4) for coastal land areas and excellent wind resource (class 5-6) for offshore areas. In some places, coastal sites are estimated to have excellent resource. Data from three different buoys in Bo Hai confirm the excellent offshore wind resource. Near the western coasts of Bo Hai, data from a meteorological tower near Huanghua and meteorological stations at Tanggu, Huanghua, and Qi-Kou confirm the class 2-3 estimates shown on the map. Data from the low elevation inland plains indicate these areas generally have low wind resource (class 1) as shown by the map.

For region 9 (primarily Shandong and northern Jiangsu), the map shows generally moderate-to-good wind resource for many coastal areas and excellent wind resource for offshore areas. In some places such as northeastern tips of Shandong Peninsula, specific coastal sites are estimated to have excellent resource. Data from meteorological stations on offshore islands confirm the good-to-excellent offshore resource. These island stations include Chang and Tuoji Islands off the northern coasts of Shandong Peninsula, Sushan and Qian-Li Islands off the southern coasts of Shandong Peninsula, and Flashing Light near Qingdao. The highest resource (class 6-7) was measured on the islands further offshore (Tuoji and Qian Li Islands), whereas the near shore islands (Chang, Sushan, and Flashing Light) indicated class 4-5 resource. The coastal site with the highest measured wind resource is Chengshantou on the northeastern tip of Shandong Peninsula, where almost 30 years of data indicated class 5-6 resource. The yearly wind resource varied from class 4 in the calmest years to class 7 in the windiest years. Data from a measurement program of seven tall-towers along the northeastern coast of Shandong Peninsula (east of Weihai) indicated generally class 3 onshore wind resource, but only one year of data were available. The map estimates show class 3-4 onshore resource along this coastal area, with class 5 in some near shore areas. Ten years of data from the meteorological station at Weihai indicate class 3-4 resource, varying from class 2-3 in the calmest years to class 4-5 in the windiest years. Inland hilltops and ridges in

Shandong Peninsula may have greater wind resource than coastal sites, as shown on the map and confirmed by a tall tower with data from the same one-year period as the seven coastal sites.

Along the southern coast of Shandong Peninsula, the wind resource can vary considerably from just class 1-2 (low-to-marginal) up to class 3-4 (good-to-excellent) at some of the best coastal sites. More than 20 years of data from a coastal meteorological station near Qingdao (on a peninsula between the bay and the ocean) indicates class 3-4 wind resource. No data were available from exposed coastal sites of northern Jiangsu, where class 2-4 is generally estimated. Data from meteorological stations in the low elevation inland areas of northern Jiangsu and southern Shandong confirm the class 1 estimates shown on the map.

The map shows many ridge crests and mountain summits in Shandong, particularly the higher mountains in central Shandong, estimated to have good-to-excellent wind resource. More than 30 years of data from a meteorological station on Taishan at elevation of 1536 m above sea level confirms class 6 (excellent) wind resource.

Southeastern Coast (Regions 12 & 14)

For region 12 (primarily Zhejiang, Shanghai, and southern Jiangsu), the map shows good-to-excellent wind resource for offshore areas including many of the islands. The wind resource in the coastal areas varies considerably from just class 1-2 (low-to-marginal) up to class 3-4 (moderate-to-good) at some of the best coastal sites. The excellent offshore resource is confirmed by data from meteorological stations on five offshore islands – Sheng Shang, Shengsi, Dachen, Dong-Gua, and Nanji Shan. Data from these islands indicate that the offshore wind resource is generally class 6, with the highest resource (class 7) measured on Dachen and Dong-Gua Islands. Data from nearshore islands and exposed coastal areas confirm the moderate-to-good wind resource for these areas. These locations included a wind measurement tower at Nanhui on the eastern tip of Shanghai and meteorological stations at Shipu and Yu-Huan in Zhejiang. North of Shanghai, onshore coastal measurement towers near Dongwangsha and Rudong confirm the class 2-3 resource shown for these areas. Micrositing is very important in coastal areas, because the wind resource can vary dramatically over short distances as indicated by the sharp gradients on the map. The wind resource inland is generally low (except on exposed elevated terrain features) as confirmed by the data from many meteorological stations.

The map shows many ridge crests and mountain summits in Zhejiang estimated to have good-to-excellent wind resource. Data from two meteorological stations on mountain summits in Zhejiang – Tianmu Shan in northwestern Zhejiang and Kuochang Shan in eastern Zhejiang – confirm this resource.

For region 14 (primarily Fujian and eastern Guangdong), the map shows excellent wind resource (largely class 6-7) for offshore areas including many of the islands. The wind resource in the coastal areas varies considerably from just class 1-2 (low-to-marginal) in sheltered bays and inlets up to class 5-6 (excellent) at some of the best coastal sites. The excellent offshore resource is confirmed by data from meteorological stations on four islands (Taishan, Mazu, Haitan, and Chinmen), wind measurement towers on Haitan and Nanao Islands, and a buoy located about 20 km south of Nanao Island. Data from measurement towers and meteorological stations in coastal areas including some islands confirm that the wind resource can vary considerably (from marginal to excellent) even among measurement towers on the same island or coastal region. Micrositing is very important, as local terrain and roughness effects can cause large variations in the wind resource especially in coastal areas with complex topography.

The map shows many ridge crests and mountain summits in Fujian and eastern Guangdong estimated to have good-to-excellent wind resource. Data were available from only one measurement site on a mountain summit – a meteorological station on Jiuxian Shan at 1650 m elevation located about 120 km southwest of Fuzhou in Fujian province. More than 30 years of data from this station indicated excellent (class 6) wind resource. Meteorological stations from inland valleys and other sheltered locations confirmed the low wind resource shown on the map for these areas.

Southern Coast and Hainan (Regions 13 & 15)

For region 13 (primarily Guangdong), the map shows generally moderate-to-good wind resource for many coastal areas and islands and excellent wind resource for some offshore areas. Data from a buoy located about 25 km southeast of Shanwei confirms the excellent offshore wind resource (class 5) shown for that area. Data from Bei-Jian Island located about 50 km south-southwest of Hong Kong indicate class 4-5 resource and confirms the good wind resource shown for that area. Data from a 6-year period at a station on Shangchuan Island indicate class 4-5 resource in the generally class 3 area on the map, and these measurement data would imply that exposed areas on islands in this region may have greater wind resource than shown by the map. Data from meteorological stations in coastal areas ranged from class 1 to class 3 wind resources (as generally indicated by the map) such as Cheung Chau (class 3), Macau (class 2), Hong Kong (class 1), Shanwei (class 1), and Tienchang (class 1).

For inland areas of region 13, data from meteorological stations confirm the low wind resource estimates shown on the map for the plains, valleys, and generally low elevation areas. The map shows areas of good-to-excellent wind resource for many of the elevated terrain features, but no measurement were available from these areas to confirm the estimates. However, weather-balloon data from meteorological stations indicate the good-to-excellent wind resource at the higher elevations.

For region 15 (Hainan, western Guangdong, and southern Guangxi), the map shows the highest wind resources are along and off the western coast of Hainan where good-to-excellent resources are estimated. No wind measurement data were available from the good-to-excellent areas, but ocean satellite wind estimates (derived largely from measurements of the state of the ocean surface) indicated accelerated wind flow and good-to-excellent wind resource off the western coast of Hainan. Data from the meteorological station at Basuo on the western coast of Hainan confirmed the class 2-3 resource estimates showed for that area. Sharp gradients of wind resource exist in this area, so micrositing is important to identify the best sites along the western coast of Hainan. The map shows class 3-4 for many other exposed coastal and offshore areas of Hainan, but no measurement data were available from these areas. The onshore coastal stations of Hainan confirmed the class 1-2 estimates shown for these areas. Meteorological stations in inland areas of Hainan confirm the class 1 estimates generally shown for the plains and lower elevations. The map shows good-to-excellent wind resource for many of the elevated terrain features of Hainan, but no measurement data were available from these areas.

For western Guangdong coastal areas east of about 110 degrees longitude, the map shows moderate (class 3) resource for many of the exposed coastal areas and increases up to class 4 for some offshore areas. Data from a coastal measurement tower located about 30 km southeast of Zhangjiang indicate class 2-3 resource and confirms the class 2-3 estimates shown for this coastal area. About one year of data from a coastal measurement tower located on the Leizhou Peninsula east of Xuwen indicate class 2 resource. The map shows a sharp gradient of wind resource in this coastal area, ranging from class 1-2 onshore to class 3 for some exposed coastal sites and just offshore.

For coastal areas of Guangdong and Guangxi west of about 110 degrees latitude, the map shows generally low-to-marginal (class 1-2) for coastal and offshore areas. Data from a meteorological station on Wei-Zhou Island confirm the class 2 estimates shown for that offshore area. Meteorological stations located in coastal areas, such as Beihai, indicated only class 1 wind resource, as shown by the map for these areas.

For inland areas of western Guangdong and southern Guangxi, data from meteorological stations confirm the low wind resource estimates shown on the map for the plains, valleys, and generally low elevation areas. The map shows areas of good-to-excellent wind resource for many of the elevated terrain features of western Guangdong and southern Guangxi, but no measurement were available from these areas to confirm the estimates.

South Central (Regions 10 & 11)

Region 10 is centered on Enshi in southwestern Hubei province and includes parts of five provinces - Sichuan, Hubei, Hunan, Guizhou, and Shanxi. The mapping area contains the region known as the "Three Gorges" located generally between Wanxian in Sichuan Province and Yichang in Hubei province. The wind map shows that the major wind resource areas are located primarily on elevated terrain features. The most prominent region displaying some areas of moderate-to-excellent wind resource is the ridges that extend from the southeast of Chongquing to the west and north of Enshi. More than 10 years of data from a meteorological station on Jinfo Shan (about 80 km southeast of Chongqing) at an elevation of 1908 meters shows class 3-4 wind resource. About one year of data from several wind measurement towers located on elevated terrain areas near Lichuan in southwestern Hubei indicate the wind resource may vary from class 1 to class 4, which shows the importance of micrositing in complex terrain. Data from the meteorological station Lu-Cong-Po located on an elevated plateau (1188 m) in southwestern Hubei confirms the class 2 wind resource shown for this area on the map. Other meteorological stations are located in valleys, basins, and sheltered areas where the wind resource is class 1 as indicated by the map.

Region 11 includes parts of four provinces – Jiangxi, Hubei, Hunan, and Anhui. The map shows a low elevation wind corridor of generally moderate-to-good wind resource in the vicinity of Poyang Lake in the northern part of Jiangxi and the lakes in the southwestern corner of Anhui. The map shows that some hills and ridges near the Poyang Lake wind corridor are estimated to have excellent wind resource. One year of data (1985) from a wind measurement tower on a hilltop site in the Poyang Lake wind corridor confirms the excellent resource shown for this area. Recent data from several different sites indicate that the wind resource can vary substantially in the complex terrain of this wind corridor, so micrositing is very important to identify the best sites.

The map shows good-to-excellent wind resource on many of the elevated terrain features in region 11. Data from the meteorological station on Lu Shan (near Jiujiang) at an elevation of 1165 m confirm the good-to-excellent resource shown for that area. A wind measurement tower on Jiugong Shan along the border between Jiangxi and Hubei confirms that good resource exists on these elevated terrain areas. Data from meteorological stations located in the plains and low elevations of region 11 (except for the wind corridor area discussed above) confirm the class 1 wind resource shown by the map for these areas.

Gross Wind Electric Potential

The wind resource classifications in the following tables match those shown on the wind resource maps. The installed capacity in the table represents gross wind electric potential not reduced by factors such as land-use exclusions, the existing transmission grid, and accessibility. The methods for converting the wind resource to wind electric potential are those used regularly by NREL. The assumptions used for the wind potential calculations are listed at the bottom of Table 1.

Each color-coded square kilometer on the map has an assigned annual wind power density at the 50-m height expressed in units of W/m^2. NREL uses a simple formula to compute the potential installed capacity in MW for grid cells with an annual wind power density of 300 W/m^2 and greater (moderate-to-excellent wind resource for utility-scale wind applications). The potential installed capacity of a grid cell was set equal to zero, if its wind power density was less than 300 W/m^2. Another scenario presented in this section included only those grid cells with an annual average power density of 400 W/m^2 and greater (good-to-excellent wind resource for utility-scale wind applications).

The estimates of windy area and potential wind capacity are listed in Table 1 for the entire onshore mapped region, and by province in Table 2. The provincial estimates shown in Table 2 may not reflect the total provincial wind potential if the entire province does not fall within the mapped region. These areas include all land on the main land mass and offshore islands, and water bodies that are entirely or part inside the main land mass of the mapped region. Offshore water areas are estimated separately in Table 3.

We estimate that there are 283,960 km^2 of areas with good-to-excellent wind resource potential in the entire onshore mapped region of China, and these windy areas represent 10.6% the mapped region. Using a conservative assumption of 5 MW per km^2, this windy area could support more than 1,400,000 MW of potential installed capacity. There are 116,577 km^2 (3.9% of the mapped region) considered to have excellent wind resource potential, and this windy area could support more than 580,000 MW of capacity.

If additional areas with moderate wind resource potential are considered, the estimated total windy area (as shown in Table 1) increases to more than 650,000 km^2. This amount of windy area represents approximately 24% of the mapped region and could support more than 3,250,000 MW of installed capacity.

Additional studies are required to accurately assess the wind electric potential, considering factors such as land-use exclusions and the existing transmission grid and accessibility.

Table 3 describes the offshore resource potential by wind power category, province and distance from shore. The offshore resource is assigned to the nearest province. We estimate that there are 132,304 km^2 of areas with good-to-excellent offshore wind resource potential in the mapped portion of China, of which 93,015 sq km^2 are considered to have excellent wind resource potential. Using a conservative assumption of 5 MW per km^2, this windy water could support more than 660,000 MW of potential installed capacity. Additional studies are required to accurately assess the wind electric potential, considering factors such as shipping lanes, water depth, and the existing transmission grid and accessibility.

If additional areas with moderate wind resource potential are considered, the estimated total windy water area (as shown in Table 3) increases to nearly 161,000 km^2. This amount of windy land could support more than 800,000 MW of installed capacity.

Table 1. China – Gross Wind Electric Potential

Good-to-Excellent Wind Resource at 50 m

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m (W/m^2)	Wind Speed at 50 m (m/s)*	Total Land Area (km^2)	Percent Windy Land	Total Capacity Installed MW
Good	4	400 – 500	7.0 – 7.5	167,383	6.3	836,915
Excellent	5	500 – 600	7.5 – 8.0	66,893	2.5	334,465
Excellent	6	600 – 800	8.0 – 8.8	35,247	1.3	176,235
Excellent	7	> 800	> 8.8	14,437	0.5	72,185
Total				283,960	10.6	1,419,800

Moderate-to-Excellent Wind Resource at 50 m

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m (W/m^2)	Wind Speed at 50 m (m/s)*	Total Land Area (km^2)	Percent Windy Land	Total Capacity Installed MW
Moderate	3	300 – 400	6.4 – 7.0	366,178	13.7	1,830,890
Good	4	400 – 500	7.0 – 7.5	167,383	6.3	836,915
Excellent	5	500 – 600	7.5 – 8.0	66,893	2.5	334,465
Excellent	6	600 – 800	8.0 – 8.8	35,247	1.3	176,235
Excellent	7	> 800	> 8.8	14,437	0.5	72,185
Total				650,138	24.3	3,250,690

*** Wind speeds assume a Weibull k value of 2.0 and sea level air density**

<u>Assumptions</u>
Installed capacity per km^2 = 5 MW
Total land area of mapped region of China = 2,676,411 km^2

Table 2. Gross Wind Electric Potential by Province

Province	Total Province Area	Total Province Area Mapped	Class 3 (km^2)	Class 4 (km^2)	Class 5 (km^2)	Class 6 (km^2)	Class 7 (km^2)	Good to Excellent Potential (MW)	Moderate to Excellent Potential (MW))	Good to Excellent Percent Windy Land	Moderate to Excellent Percent Windy Land
Anhui	140,225	33,599	596	177	12	7	0	980	3,960	0.6%	2.4%
Beijing	16,604	16,604	728	512	260	282	247	6,505	10,145	7.8%	12.2%
Fujian	121,119	96,606	3,805	1,581	817	729	278	17,025	36,050	3.5%	7.5%
Gansu	125,118	4,452	925	131	14	1	0	730	5,355	3.3%	24.1%
Guangdong	210,035	189,656	3,390	881	287	54	5	6,135	23,085	0.6%	2.4%
Guangxi	228,860	69,836	1,123	295	90	22	1	2,040	7,655	0.6%	2.2%
Guizhou	142,734	10,037	151	12	1	0	0	65	820	0.1%	1.6%
Hebei	186,623	133,934	16,904	9,881	4,807	4,009	2,183	104,400	188,920	15.6%	28.2%
Heilongjiang	431,182	329,457	17,937	4,013	1,435	677	26	30,755	120,440	1.9%	7.3%
Henan	166,034	31	0	0	0	0	0	0	0	0.0%	0.0%
Hubei	186,188	90,723	863	130	26	0	0	780	5,095	0.2%	1.1%
Hunan	211,468	47,183	143	38	20	0	0	290	1,005	0.1%	0.4%
Jiangsu	99,670	93,914	1,609	340	12	0	0	1,760	9,805	0.4%	2.1%
Jiangxi	167,970	65,827	1,389	256	110	0	0	1,830	8,775	0.6%	2.7%
Jilin	191,374	122,616	23,202	1,059	270	91	10	7,150	123,160	1.2%	20.1%
Liaoning	146,621	131,330	29,863	6,219	1,920	746	91	44,880	194,195	6.8%	29.6%
Nei Mongol	1,009,698	833,522	241,601	134,980	54,924	27,457	11,223	1,142,920	2,350,925	27.4%	56.4%
Ningxia	51,990	36,017	3,810	1,236	489	330	99	10,770	29,820	6.0%	16.6%
Shaanxi	203,399	37,655	1,844	180	3	0	0	915	10,135	0.5%	5.4%
Shandong	155,637	122,920	8,014	2,339	276	27	0	13,210	53,280	2.1%	8.7%
Shanghai	5,991	5,991	105	16	1	0	0	85	610	0.3%	2.0%
Shanxi	156,090	30,268	4,295	1,989	815	704	271	18,895	40,370	12.5%	26.7%
Sichuan	182,955	74,584	1,508	297	53	27	3	1,900	9,440	0.5%	2.5%
Tianjin	11,283	11,283	359	136	0	0	0	680	2,475	1.2%	4.4%
Zhejiang	100,456	88,366	2,014	685	251	84	0	5,100	15,170	1.2%	3.4%
Total	4,649,324	2,676,411	366,178	167,383	66,893	35,247	14,437	1,419,800	3,250,690	10.6%	24.3%

Assumptions
Installed capacity per km^2 = 5 MW

Table 3. Gross Offshore Wind Electric Potential by Province and Distance from Shore

Moderate to Excellent Wind Resource by Province

Province	Wind Class	Area (km^2) by Distance from Shore 0 - 10 km	10 - 20 km	> 20 km	Total Area (km^2)		Potential (MW) by Distance from Shore 0 - 10 km	10 - 20 km	> 20 km	Total Potential (MW)
Fujian	3	885	3	0	888		4,425	15	0	4,440
	4	878	1	0	879		4,390	5	0	4,395
	5	1,142	41	0	1,183		5,710	205	0	5,915
	6	3,049	727	132	3,908		15,245	3,635	660	19,540
	7	4,807	4,316	1,412	10,535		24,035	21,580	7,060	52,675
	Mod. to Excellent	*10,761*	*5,088*	*1,544*	*17,393*		*53,805*	*25,440*	*7,720*	*86,965*
	Good to Excellent	*9,876*	*5,085*	*1,544*	*16,505*		*49,380*	*25,425*	*7,720*	*82,525*
Guangdong	3	12,115	4,128	53	16,296		60,575	20,640	265	81,480
	4	7,325	8,804	2,049	18,178		36,625	44,020	10,245	90,890
	5	1,650	3,050	148	4,848		8,250	15,250	740	24,240
	6	962	838	42	1,842		4,810	4,190	210	9,210
	7	111	479	35	625		555	2,395	175	3,125
	Mod. to Excellent	*22,163*	*17,299*	*2,327*	*41,789*		*110,815*	*86,495*	*11,635*	*208,945*
	Good to Excellent	*10,048*	*13,171*	*2,274*	*25,493*		*50,240*	*65,855*	*11,370*	*127,465*
Guangxi	3	102	632	6	740		510	3,160	30	3,700
	4	0	0	0	0		0	0	0	0
	5	0	0	0	0		0	0	0	0
	6	0	0	0	0		0	0	0	0
	7	0	0	0	0		0	0	0	0
	Mod. to Excellent	*102*	*632*	*6*	*740*		*510*	*3,160*	*30*	*3,700*
	Good to Excellent	*0*	*0*	*0*	*0*		*0*	*0*	*0*	*0*
Hebei	3	381	0	0	381		1,905	0	0	1,905
	4	595	442	0	1,037		2,975	2,210	0	5,185
	5	1,335	381	11	1,727		6,675	1,905	55	8,635
	6	392	1,741	654	2,787		1,960	8,705	3,270	13,935
	7	0	0	0	0		0	0	0	0
	Mod. to Excellent	*2,703*	*2,564*	*665*	*5,932*		*13,515*	*12,820*	*3,325*	*29,660*
	Good to Excellent	*2,322*	*2,564*	*665*	*5,551*		*11,610*	*12,820*	*3,325*	*27,755*

Province	Wind Class	Area (km^2) by Distance from Shore			Total		Potential (MW) by Distance from Shore			Total
		0 - 10 km	10 - 20 km	> 20 km	Area (km^2)		0 - 10 km	10 - 20 km	> 20 km	Potential (MW)
Jiangsu	3	954	1	0	955		4,770	5	0	4,775
	4	2,803	766	3	3,572		14,015	3,830	15	17,860
	5	1,807	3,741	406	5,954		9,035	18,705	2,030	29,770
	6	0	0	0	0		0	0	0	0
	7	0	0	0	0		0	0	0	0
	Mod. to Excellent	*5,564*	*4,508*	*409*	*10,481*		*27,820*	*22,540*	*2,045*	*52,405*
	Good to Excellent	*4,610*	*4,507*	*409*	*9,526*		*23,050*	*22,535*	*2,045*	*47,630*
Liaoning	3	1,584	1	0	1,585		7,920	5	0	7,925
	4	2,904	1,103	25	4,032		14,520	5,515	125	20,160
	5	5,815	2,948	76	8,839		29,075	14,740	380	44,195
	6	2,367	6,061	335	8,763		11,835	30,305	1,675	43,815
	7	0	0	0	0		0	0	0	0
	Mod. to Excellent	*12,670*	*10,113*	*436*	*23,219*		*63,350*	*50,565*	*2,180*	*116,095*
	Good to Excellent	*11,086*	*10,112*	*436*	*21,634*		*55,430*	*50,560*	*2,180*	*108,170*
Shandong	3	2,540	189	0	2,729		12,700	945	0	13,645
	4	3,549	2,394	49	5,992		17,745	11,970	245	29,960
	5	4,406	3,946	652	9,004		22,030	19,730	3,260	45,020
	6	2,683	5,322	781	8,786		13,415	26,610	3,905	43,930
	7	0	0	0	0		0	0	0	0
	Mod. to Excellent	*13,178*	*11,851*	*1,482*	*26,511*		*65,890*	*59,255*	*7,410*	*132,555*
	Good to Excellent	*10,638*	*11,662*	*1,482*	*23,782*		*53,190*	*58,310*	*7,410*	*118,910*
Shanghai	3	1,169	372	85	1,626		5,845	1,860	425	8,130
	4	860	697	342	1,899		4,300	3,485	1,710	9,495
	5	73	590	113	776		365	2,950	565	3,880
	6	1	2	0	3		5	10	0	15
	7	0	0	0	0		0	0	0	0
	Mod. to Excellent	*2,103*	*1,661*	*540*	*4,304*		*10,515*	*8,305*	*2,700*	*21,520*
	Good to Excellent	*934*	*1,289*	*455*	*2,678*		*4,670*	*6,445*	*2,275*	*13,390*

Province	Wind Class	Area (km^2) by Distance from Shore			Total Area (km^2)	Potential (MW) by Distance from Shore			Total Potential (MW)
		0 - 10 km	10 - 20 km	> 20 km		0 - 10 km	10 - 20 km	> 20 km	
Tianjin	3	36	0	0	36	180	0	0	180
	4	164	0	0	164	820	0	0	820
	5	592	527	5	1,124	2,960	2,635	25	5,620
	6	84	32	0	116	420	160	0	580
	7	0	0	0	0	0	0	0	0
	Mod. to Excellent	*876*	*559*	*5*	*1,440*	*4,380*	*2,795*	*25*	*7,200*
	Good to Excellent	*840*	*559*	*5*	*1,404*	*4,200*	*2,795*	*25*	*7,020*
Zhejiang	3	2,765	652	32	3,449	13,825	3,260	160	17,245
	4	2,610	577	349	3,536	13,050	2,885	1,745	17,680
	5	3,487	1,490	121	5,098	17,435	7,450	605	25,490
	6	6,596	7,745	2,419	16,760	32,980	38,725	12,095	83,800
	7	69	53	215	337	345	265	1,075	1,685
	Mod. to Excellent	*15,527*	*10,517*	*3,136*	*29,180*	*77,635*	*52,585*	*15,680*	*145,900*
	Good to Excellent	*12,762*	*9,865*	*3,104*	*25,731*	*63,810*	*49,325*	*15,520*	*128,655*
Total	3	22,531	5,978	176	28,685	112,655	29,890	880	143,425
	4	21,688	14,784	2,817	39,289	108,440	73,920	14,085	196,445
	5	20,307	16,714	1,532	38,553	101,535	83,570	7,660	192,765
	6	16,134	22,468	4,363	42,965	80,670	112,340	21,815	214,825
	7	4,987	4,848	1,662	11,497	24,935	24,240	8,310	57,485
	Mod. to Excellent	*85,647*	*64,792*	*10,550*	*160,989*	*428,235*	*323,960*	*52,750*	*804,945*
	Good to Excellent	*63,116*	*58,814*	*10,374*	*132,304*	*315,580*	*294,070*	*51,870*	*661,520*