User Manual for SWERA:

Designing Renewable Resource Assessment Projects and Using Assessment Products

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1. Introduction to SWERA

The *SWERA Programme provides easy access to credible renewable energy data to stimulate investment in, and development of, renewable energy technologies.*

1.1 History of SWERA

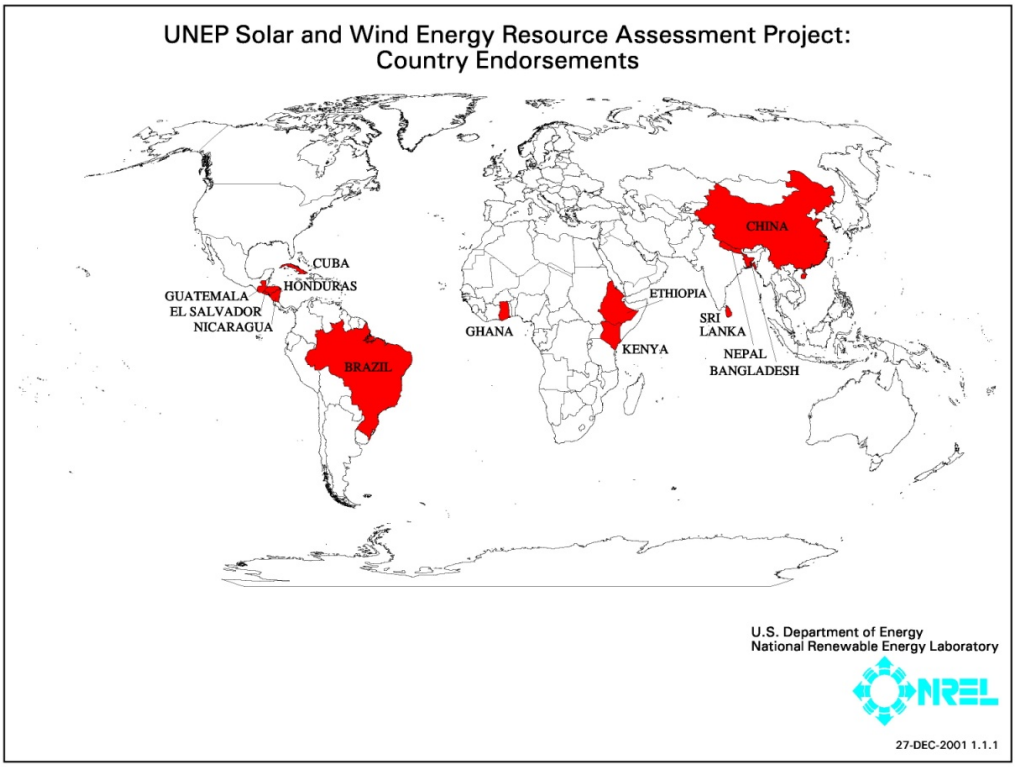
The Solar and Wind Energy Resource Assessment (SWERA) started in 2001 to advance the large scale use of renewable energy technologies by increasing the availability and accessibility of high quality solar and wind resource information. SWERA began as a pilot project with funding from the Global Environment Facility (GEF) and managed by the United Nations Environment Programme's (UNEP) Division of Technology, Industry and Economics (DTIE) in collaboration with more than 25 partners around the world. With the success of the project in 13 pilot countries SWERA expanded in 2006 into a full programme. Its expanded mission is to provide high quality information on renewable energy resources for countries and regions around the world, along with the tools needed to apply these data in ways that facilitate renewable energy policies and investments.

Slowing and reversing growth in greenhouse gas (GHG) emissions will require, in part, large-scale applications of renewable energy technologies (RETs). While large-scale deployments have grown in recent years, the majority of this growth has occurred in Europe and the United States. Lack of credible data on renewable resource availability has inhibited wide-scale investment in RETs. The economics of renewable energy projects are very sensitive to available resources and proximity of those resources to transmission grids and load centers. The absence of credible data on these elements poses a critical barrier to public-sector and private-sector investment in renewable energy applications in many parts of the world.

The GEF co-financed US$ 6.8 million of the US$ 9.1 million pilot project with the aim of removing the informational obstacles preventing large-scale investment in renewable energy. The pilot project's objective was to make available reliable, high resolution solar and wind resource data in developing countries to support more informed

decision-making, science-and-technology based policy, and increased investor interest in renewable energy.

Initial project countries were selected through an invitation that included a partnership agreement between SWERA and each study country. The 13 pilot countries were Bangladesh, Brazil, China, Cuba, El Salvador, Ethiopia, Ghana, Guatemala, Honduras, Kenya, Nepal, Nicaragua, and Sri Lanka. With the success of the pilot project, SWERA expanded to a full programme in 2006 with aims to increase the global coverage of renewable resource data.



Through this increased availability of renewable resource data, the SWERA programme will allow for better identification of potential projects and better informed decision-making, hence reducing project planning time, as well as investor risk.

1.2 SWERA functioning

SWERA brings together considerable technical expertise in renewable energy resource assessments. The programme began with a collaborative management structure with an Advisory Board, Steering Body, Technical Teams and Task Groups. As the programme continues to evolve, so too do the functions of each of these groups. UNEP provides the core secretariat functions of maintaining and expanding the SWERA programme, evaluating impacts, and maintaining and developing programme documents.

From the inception of the initial SWERA pilot project through to current activities, the overall management and development of SWERA has been coordinated through UNEP. During the project's initiation, an Advisory Board was convened to provide guidance on successful design and implementation of the programme, and these contributions have continued on an as-requested basis.

For the original SWERA pilot project, a technical team was assembled to establish the data quality criteria for SWERA products and to develop the data products, in partnership with in-country experts, for the initial 13 countries. Upon completion of the pilot project, the technical team has continued to contribute to the SWERA programme by providing ideas for enhancing the program, exploring opportunities to add to the database with products developed under other projects, and developing proposals to expand renewable resource assessment science and global coverage.

The original technical team consisted of the US National Renewable Energy Laboratory (NREL), Brazil's National Institute for Space Research (INPE), the State University of New York (SUNY), the German Aerospace Center (DLR), Denmark's Risø-DTU (Technical University of Denmark) National Laboratory for Sustainable Energy (Risø), The Energy and Resources Institute in India (TERI), and the UNEP Global Resource Information Database (UNEP/GRID)-Sioux Falls. These were the implementing agencies for the original mapping, database and GIS activities. As the programme continues to grow, additional partners may be brought in as members to the technical team and contributors of SWERA resource data.

The original pilot project also involved regional co-ordinators and in-country partners. TERI and INPE assisted with regional SWERA activities including regional meetings bringing together stakeholders. National stakeholders are brought in as partners for each SWERA activity, and these often include individuals from electrical utilities,

private sector solar and wind energy technology providers, NGOs, Ministries of Energy, Ministries of Meteorology and other relevant government departments. In-country participation ensures that the resource data products are sufficiently validated, that the most recently available infrastructure data are incorporated into the data products, and that the final products meet the needs of planning agencies and project developers.

The success of SWERA activities has depended on the sustained contributions of UNEP, the technical teams, and the in-country experts and stakeholders. Any future SWERA activities will build on this successful model to ensure effective removal of informational obstacles to renewable energy investment.

1.3 Flexible funding

The majority of funding for the SWERA pilot project, which began in 2001, was provided by the GEF. As SWERA expanded into a full programme in 2006, the SWERA team began exploring options for a new funding approach. Additional data products have been added to the SWERA database as a result of external funding to the technical team for SWERA like activities outside the umbrella of SWERA.

The US Agency for International Development (USAID) provided funding for resource assessments in Afghanistan and Pakistan; these are already available through the SWERA web site. USAID is also supporting SWERA-type assessments for Bhutan, and new SWERA assessments for the United Arab Emirates (UAE) have been funded by the Abu Dhabi Future Energy Company as part of the MASDAR initiative. The Bhutan and UAE products will be made available on the SWERA web site when completed.

In 2006, the U.S. National Aeronautics and Space Administration (NASA) agreed to fund a US$ 1 million 3-year project to continue the evolution of SWERA into a distributed and global decision support system and to prototype complementary small hydro power assessments utilizing NASA Earth-Science research results. The SWERA web site has been enhanced through this initiative to improve user access to available data products and information about the programme.

Data products produced by SWERA technical partners will be added to the SWERA database and interactive mapping system as they come available. Funding for SWERA projects in a new region can be sought from local governments, international funding agencies, or other sources.

1.4 SWERA's plans for the future

One of SWERA's strengths is the ability to place critical solar and wind energy resource maps and data in the public domain. Therefore, the expanded SWERA programme offers an open architecture that allows including new countries and partners. With this model, SWERA intends to increase global coverage of high quality wind and solar resource data and eliminate that informational barrier to investment in renewable energy projects. SWERA also aims to incorporate additional resource assessment types, such as small hydro, geothermal and biomass, for use for the SWERA user community, as such resource assessments become well defined and widely available. Over time, the

utility of SWERA database for national planning and initial project development exploration will continue to grow in geographic coverage and technological scope.

The SWERA programme has evolved from a project-centric structure having primary engagement with key technical institutions in 13 countries to a programme that encourages participation of all countries and its citizens. The redesigned decision support system is meant to increase easy accessibility to existing high-resolution resource data at no cost to all interested user communities. High-resolution SWERA resource data does not yet have global coverage; however, lower-resolution global data sets from NASA have been added to the database, which can be used until higher-resolution data sets become available.

The expanded SWERA programme aims to include new countries and partners. SWERA also intends to provide training material to users in developing countries, which will contribute to the knowledge and development of renewable energy assessments. By continuing to provide easy access to renewable resource data and increasing the global coverage of the data, SWERA will continue to remove the informational barriers preventing large-scale investment in renewable energy throughout the world.

2. How to get started with SWERA in a new country which has not yet been covered in the project

SWERA welcomes the inclusion of all credible national renewable energy resource assessments into the SWERA programme. These can either be existing resource assessments or SWERA partners can work with agencies to create new resource assessments.

2.1 Is SWERA right for my region?

SWERA is right for all regions desiring to better understand their indigenous energy options. With renewable resources, knowledge is power, and SWERA projects deliver that knowledge into the hands of consumers, government and industry. Solar, wind, geothermal, biomass, hydro, and wave resources have the potential to meet the world's energy demands. However, they are not evenly distributed and can vary greatly within even small geographic regions. Without timely and reliable assessments of the size and scale of a particular resource, countries cannot direct support towards initiatives that best exploit their available resources and investors cannot determine whether a particular project will be viable, including the potential return on their investment.

Support from the country and the intent to use the renewable energy information is important to the success of a SWERA project. Growing energy demand, which is occurring in almost all countries, and the increasing energy gap tends to heighten interest in renewable energy. Evidence of political commitment can be determined by looking at membership in organization such as the Johannesburg Renewable Energy Coalition. High quality assessments of renewable energy resources also allow national and state energy agencies to establish long-term and scientifically robust sustainable energy supply options and policies, including plans and polices by environmental agencies to reduce greenhouse gas emissions.

The relative costs to assess renewable energy resources are low compared with actual project costs. With reliable and timely resource data, project developers can gain confidence their projects will be successful and profitable.

2.2 Basics of Implementation

Implementing a SWERA project in a new country or region involves completing regional resource assessments. Based on the needs of the region and resources available, the following project parameters must be established:

- Regional coverage: state or province level, whole country, multiple countries
- Renewable energy sources to be evaluated
- Types of products and in which formats the products will be produced
- Partners and roles and responsibilities of each partner

Ideally the push for a SWERA assessment should come from the country. But the nature of the SWERA approach and its use of remote sensing favors economy of scale; mapping two adjacent countries of roughly the same size at once costs much less than doing each

separately. Hence there is some logic of doing regional or sub-regional assessments and assembling groups of countries into a common effort. Regardless of where a project originates, SWERA's success relies on strong involvement of partners from the project countries. In-country collaborators are more likely to have access to the most up-todate spatial data for inclusion in data products and analysis tools, further increasing the utility of the final products for energy and project planning. Strong investment of the local energy and development community also ensures that the final SWERA products are sufficiently validated, are in formats useful to the organizations most likely to use them, and are publicized to reach the broader user community within a country.

The biggest barriers to starting a SWERA project are similar to those in most projects: developing the project scope, identifying partners and establishing project funding. Once the scope and funding have been clearly established, the resource assessments are conducted. Final maps, data products, and analysis tools are created using the resource assessment data and other relevant spatial data sets collected by the country partners. SWERA projects are then generally concluded with outreach and training events to build in-country capacity on how to use the resource data for renewable energy planning.

For more detailed and project-specific information, interested parties, should contact Daniel Puig at UNEP/DTIE (daniel.puig@unep.fr).

2.3 Length of SWERA projects

How long it takes to complete a SWERA project will depend on the scope of the resource assessments being done. A reasonable time frame for a project involving solar resource assessment is one year. Project length may be greater than one year for projects including wind resource assessments or when time and data constraints are encountered.

2.4 Partner Roles and Responsibilities

SWERA's success is based on its collaborative nature, which involves commitment and investments of all of the partners working on a given project. The partner roles described below are guidelines to illustrate what is expected of each of the main contributors: UNEP, the SWERA technical team, and in-country partners.

2.4.1 UNEP

UNEP/DTIE is the managing organization for SWERA, and all SWERA projects are coordinated through UNEP. UNEP/DEWA maintains the SWERA website and database. UNEP fulfills the general secretariat function for SWERA and works to expand the programme's impact on global renewable energy deployment. UNEP also evaluates the programme's impacts and develops and maintains programme documents. As a central node for SWERA's operations, UNEP has a unique vantage point that allows them to match a country's needs with technical team capabilities and identify potential funding opportunities for countries wishing to undertake a SWERA assessment. UNEP can identify which technical team members are best suited to assessments in a given region or identify new technical team members that can contribute to resource assessment

efforts.

2.4.2 SWERA Technical Team

Members of the SWERA technical team lead the resource assessments. Their combined expertise in resource assessment methodology means that countries will have the best possible regional data for use in renewable energy planning. The technical team will communicate their data needs to country partners, share interim results, incorporate feedback, and produce final data and map products in agreed-upon formats. The technical team members work closely with both UNEP and the in-country partners to ensure the successful execution of each SWERA project.

2.4.3 Country Partners

Country partners are key participants in any SWERA project. They are responsible for collecting available measured meteorological data and spatial data sets relevant for renewable energy planning (e.g. transportation and electricity infrastructure). Country partners are also responsible for soliciting and collecting feedback from resource and meteorology experts on initial products. Finally, country partners are key to ensuring that the final SWERA products reach those best positioned to use the data.

2.5 Resource Assessment Methods in SWERA

Provision of reliable resource data is a key objective of SWERA, and the technical team uses state-of-the-science methodologies to produce these data products. Below are brief descriptions of how SWERA products are developed.

2.5.1 Solar resource assessment

The best estimates of solar resource available for renewable energy applications are determined through collection of ground-measured data. These estimates collected at points can be used to calibrate and validate national solar resource assessments created using numerical models incorporating meteorological and satellite data.

The SWERA technical team uses data collected from geostationary satellites as a primary input into their models. The visible channel from geostationary satellites provides information on the reflection of the earth-atmosphere system, while the infared channel provides surface and atmosphere temperature information, which supplies information necessary to determine the extent of cloud cover. Additional input data are required for model estimation of solar resource and include elevation, ozone, water vapor, aerosol, elevation, and snow cover data. Model outputs are validated against available ground data to ensure the quality of the final data products.

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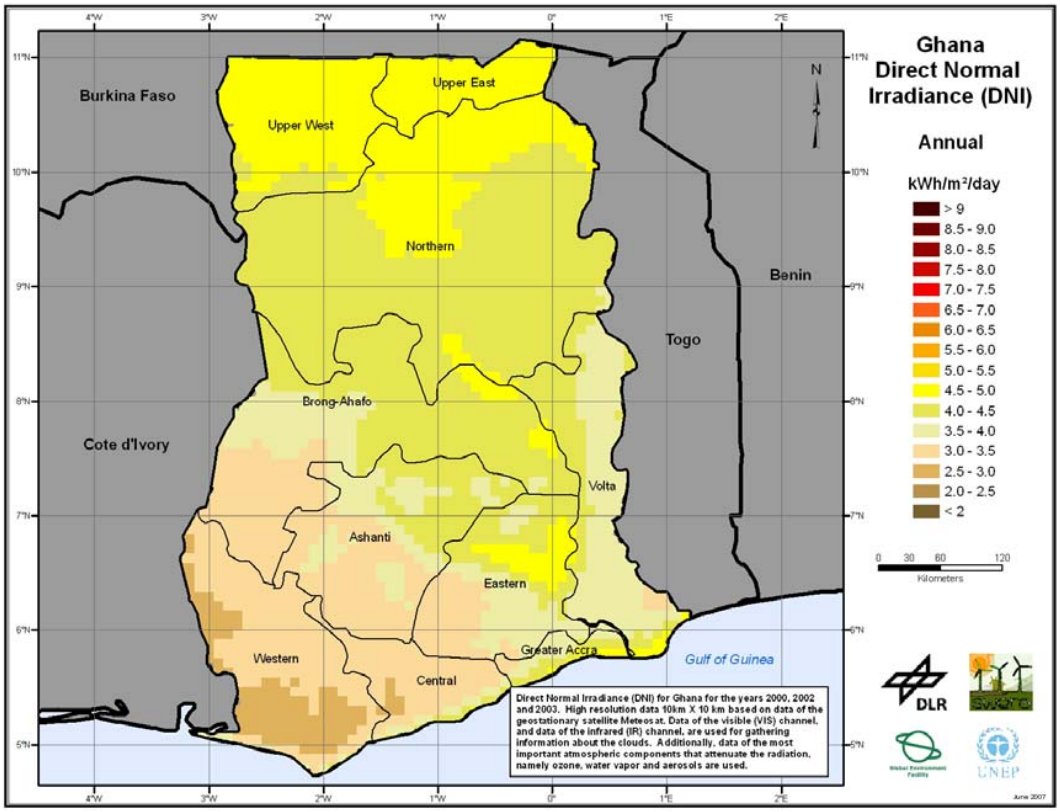
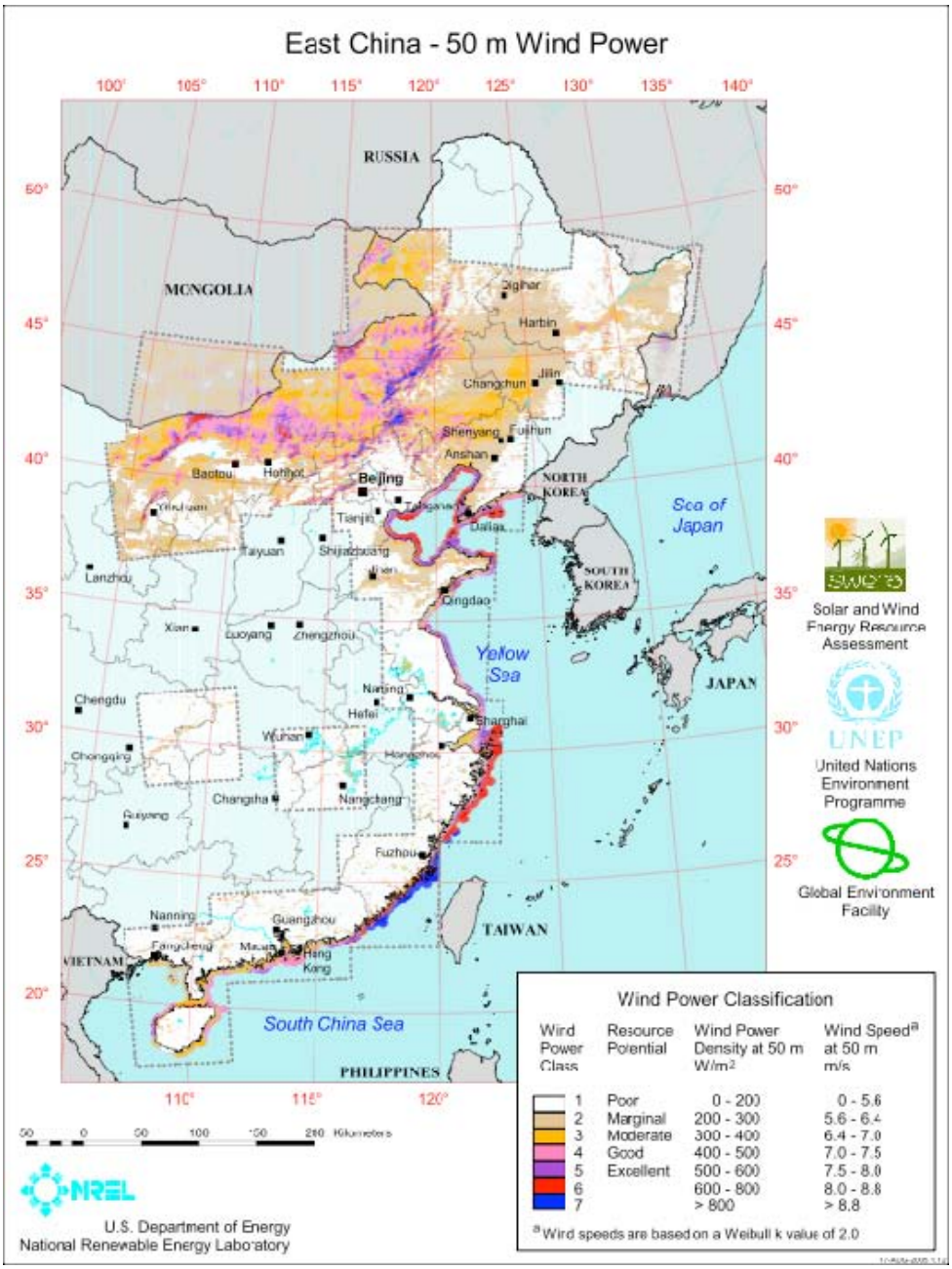


This methodology allows for estimation of solar resource available for flat-plate and concentrating solar applications over large geographic areas at high spatial resolution.

2.5.2 Wind resource assessment

For planning wind energy projects, the best and most reliable wind data would be obtained from an anemometer collecting data at a specific site over the course of one year or longer. This level of detailed wind data is essential for siting any wind energy equipment, but this method is impractical for estimating wind resource over large geographic areas. Instead, wind resource assessment experts employ numerical models validated with available measured data to produce wind resource data at high spatial resolution over large regions.

The SWERA technical team relies on mesoscale models and available existing observed and modeled data to estimate wind resource across a region. Data sets used by the SWERA technical team include measured data from surface and upper air stations, historical ship wind observation, modeled ocean winds derived from satellite data, modeled upper air data, and topographical data. Wherever available, other more detailed data sets are included.



In-country data from meteorological towers are essential to a complete on-shore wind resource assessment. To obtain these data, queries should be made of local and regional meteorological departments, who should either be able to provide data or identify the appropriate sources. Due to microclimate effects caused by landforms, wind resource assessments tend to be higher resolution than solar assessments to capture local regions of high potential along ridges, canyons and shorelines.

2.6 Product data formats

A key component of SWERA is development of datasets in spatial formats produced in a geographic information system (GIS). Producing data products in this manner allows for analysis of the relationship between available renewable resources and other relevant elements, such as existing transportation and electricity infrastructure, protected lands, and load centers. SWERA resource assessment data exist in the public domain in the form of maps for easy visual inspection of the resource and data products for use in analysis.

All SWERA data products are produced in standardized formats, and the specification requirements are shared by all data providers. This standardization increases the usability of products and allows for easy incorporation into the SWERA interactive mapping system.

3. How to use the SWERA products in a country where information is available in the database.

3.1 What products are available through SWERA?

This section briefly describes the types of products available through the SWERA web site, including maps, data products, documents and analysis tools. In most cases SWERA products are only available in English, though in a few instances the products are in the primary language of the country that is the focus of that particular product.

3.1.1 SWERA Solar Resource Products

SWERA solar products provide information on the solar resource at a specific location that is available for use by solar technologies. These products include maps and data of available solar resource, as well as documentation on the methodology employed to generate these solar resource estimates. The data products and resource maps are derived from models and satellite and global weather observations and do not contain site-specific measurement information. SWERA solar products are classified by the radiation components they describe. Applicability of the different radiation components to the relevant technologies is described below.

Solar resource maps

SWERA solar resource map products provide visual presentations of the solar resource. These maps can be used to visually identify areas rich in solar resources within a country or region, and allow an easy look at the data without the need to navigate through large data sets or to apply GIS software. On each map the resource potential is presented for a series of contiguous grid cells. The grid resolution will vary for different maps (e.g. 10 km, 40 km, 1°, etc.), and the specific resolution is noted on each map. The renewable resource potential for each cell is displayed as a color corresponding to a certain value, which can be determined by referencing the scale bar on each map. The value of the resource potential for a grid cell is also specific to a defined time period. Some maps may display annual average values and others may present data for each month or season. The time period for which the data applies is noted on each map.

SWERA solar resource maps are available for different solar radiation components, which are applicable to different solar energy technologies. More information about solar radiation components and technologies is provided in the sections on SWERA products for flat plate and concentrating collectors.

Solar data products

The solar data products can help users estimate the size of a system that would be needed to meet specified loads and whether projects that incorporate these components are economically feasible. The data serve as a screening tool to eliminate areas or applications that are not suitable for solar technologies, and to guide developers to promising regions and applications. Although the majority of the solar data are presented as monthly or annual averages, site-specific data with much finer temporal resolution are also available (see Typical Meteorologic Year (TMY) data). Most

data products available through SWERA are in GIS format, though some hourly, site-specific data sets can be found in a spreadsheet format. The GIS data sets contain the source data used to develop the SWERA map products and will contain the resource data in similar spatial resolutions, including grid cell sizes of 10-km and 40-km. These data sets can be used in any GIS system to perform several tasks, including data capture, data management, data manipulation, data analysis, and presentation of results in graphic or report forms.

As with the SWERA solar resource maps, SWERA solar resource data are available for different solar radiation components, which are applicable to different solar energy technologies.

SWERA products for flat-plate solar collectors

Flat plate solar collectors (photovoltaic (PV), solar hot water heating systems, etc.) can use all radiation components that reach the collector (Figure 1). This usable solar radiation includes the direct, diffuse and ground-reflected components. SWERA solar data products for flat plate collectors are available for two orientations of collectors on fixed mounts: horizontal and latitude tilt. SWERA maps and data are available for both of these orientations.

Figure 1. Photovoltaic panels.

Horizontal Flat-Plate Collectors

Global Horizontal Irradiance (GHI) products describe the solar resource available to a flat-plate collector oriented horizontal to the earth's surface.

Tilted Flat-Plate Collectors

Flat-plate tilted at latitude (Tilt) SWERA products represent the solar resource available

to a flat plate collector oriented toward the equator at an angle from horizontal equal to the latitude of the collector location. This collector orientation is typical practice for PV system installation, although other orientations are also used.

In some locations a latitude tilt orientation will not be optimal due to local weather conditions, such as morning fog or afternoon showers, or diurnal and seasonal load profiles. Some analytical tools, such as HOMER, use GHI data as inputs, which are adjusted for latitude tilt differences within the model.

SWERA products for concentrating solar collectors

The Direct Normal Irradiance (DNI) products are relevant for concentrating solar applications (Figure 2). They describe the solar resource available to concentrating solar power (CSP) systems that track the sun throughout the day. Concentrating solar power (CSP) systems are a technology that uses concentrating solar collectors to provide high temperatures for running steam turbine generators. The SWERA archive contains maps and data of DNI resources.

Figure 2. Parabolic trough concentrating solar collector.

Additional SWERA solar products

The SWERA archive also houses some data sets of diffuse solar radiation. The diffuse data sets are equal to the global horizontal radiation minus the direct component. If only one of either the GHI or DNI data sets are available, the diffuse data set can be used to estimate the missing data. Diffuse radiation data are also useful for validating radiative transfer models, and have applications in building design where daylighting is a consideration.

3.1.2 SWERA Wind Resource Products

SWERA wind products provide estimates of how much wind resource is available at potential development sites. SWERA wind resources are depicted as average wind

speed (meters per second, m/s) or wind power density (watts per square meter, W/m^2) at a specified height above the ground (nominally 50 m). These are derived from models and satellite and global weather observations and do not contain site-specific data. The SWERA high-resolution (such as 1-km and 5-km) gridded data products allow for identification of resource rich areas that could be missed in lower resolution data sets. The SWERA wind products can be used to determine what areas warrant further investigation for wind development. These products are not intended to be used for siting decisions, especially wind farms, but instead should be used to identify potential areas for wind farms at which more detailed time-series site-specific data should be collected.

Wind resource maps
The SWERA wind maps provide visual presentations of how much wind energy is available at potential development sites. These maps can be used to visually identify areas rich in wind resources within a country or region and allow an easy look at the data without the need to navigate through large data sets or applying GIS software. For more detailed investigations, users should explore the wind data sets available through the SWERA database.

Wind data products
The SWERA data sets allow users to compare the resource availability of different regions and to develop preliminary analysis of wind energy production for various types of turbines. Before using these data in analyses, please confirm the data required by your wind energy simulation algorithm (wind speed, wind power, height above ground, etc.) and make adjustments as necessary.

3.1.3 SWERA documents

SWERA documents describe the SWERA programme and provide documentation related to SWERA activities and renewable energy in SWERA countries.

SWERA Programme documents
The SWERA archive contains overview documents related to SWERA including fact sheets, presentations and the full SWERA project document.

Solar and wind documentation
The solar and wind documentation products are text documents that describe the methods employed to develop the solar resource products under the SWERA programme. In some cases, the methods described are specific to a SWERA country. In others, the documentation may not even discuss a SWERA country but the development of the methodology used to estimate solar resources, which were then replicated for some SWERA countries.

National Assessments
In some SWERA countries, the national partners provided an overview of the status of renewable energy and the potential revealed through the country's participation in SWERA. The format of these documents varies and may be presented as renewable energy case studies or overviews of installed renewable capacity and potential for expansion.

3.1.4 SWERA Tools

The energy analysis tools available through SWERA allow users to interactively explore the data available through SWERA without requiring specialized GIS expertise and to analyze the economic aspects of renewable energy projects using SWERA's resource data in modeling tools. Details on how to get started using these tools are discussed in sections 3.5 to 3.7.

Renewable energy Resource EXplorer (RREX)

The SWERA Renewable energy Resource EXplorer (RREX) is an on-line Geographic Information System tool for viewing renewable resource data. Through this interactive system, users can view several renewable resource data sets available through SWERA.

Generally speaking, the data sets that are at a finer resolution (smaller grid cells, such as 1 km to 10 km) will be the most useful in determining the suitability of renewable energy systems for a given location as they can better capture variations around smaller geographic features. As there is currently not global coverage of high-resolution resource data, RREX also includes lower-resolution global data sets. Though these will not adequately capture the details of resource availability at a given site, they can provide users with generalized patterns of solar and wind resources.

Geospatial Toolkits

A Geospatial Toolkit (GsT) is a map-based software application that integrates resource data and geographic information systems (GIS) capabilities for decision-making, policy analysis, and planning for future renewable energy projects. The GsTs are stand-alone software applications that can be downloaded and run on a Microsoft Windows® based operating system. Each GsT is specific to a country or province and has the available renewable resource assessment data packaged with the software. After downloading and installing the GsT, users can view map layers containing geographical data and perform queries to identify possible locations to harness renewable energy.

The underlying renewable resource data used to produce the GsTs is also available to users in GIS format. The data available through SWERA are in standard shape and image file formats, which can be read by most open source and commercial GIS, internet mapping and image processing software. The available data includes both resource data (which may also include seasonal and diurnal resource characteristics) and relevant geospatial data (land use, road and railway networks, etc). Some countries may have GsT data sets without having a GsT, if one or more resource assessments was not completed in the first phase of SWERA. These data sets are also in standard GIS formats and so can be used by most GIS software.

HOMER

HOMER is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications. HOMER's optimization and sensitivity analysis algorithms allow the user to evaluate the economic and technical feasibility of a large number of technology options and to account for variation in technology costs and energy resource availability. HOMER simulates both conventional and renewable

energy technologies and finds the least cost combination of components that meets electrical and thermal loads.

HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. After simulating all of the possible system configurations, HOMER displays a list of feasible systems, sorted by lifecycle cost. You can also perform a sensitivity analysis on most inputs to examine the effect of changes in the value on the results.

RETScreen
The RETScreen International Clean Energy Project Analysis Software is a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used worldwide to evaluate the energy production and savings, life-cycle costs, emission reductions, financial viability and risk for various types of energy efficient and renewable energy technologies (RETs). The software also includes product, cost and climate databases, and a detailed online user manual. Other tools include: a case study based on a college/university-level training course; an engineering electronic textbook; and an extensive Website. All of these tools are available free-of-charge in English and French, with many of the tools available in other languages.

The RETScreen International Clean Energy Decision Support Centre seeks to build the capacity of planners, decision-makers and industry to implement renewable energy and energy efficiency projects. This objective is achieved by: developing decision-making tools (e.g. RETScreen Software) that reduce the cost of pre-feasibility studies; disseminating knowledge to help people make better decisions; and by training people to better analyse the technical and financial viability of possible projects. RETScreen International is managed under the leadership and ongoing financial support of Natural Resources Canada's (NRCan) CANMET Energy Technology Centre - Varennes (CETC-Varennes).

3.2 Value of SWERA products compared to other assessments

The resource assessment maps and data products in SWERA were developed using numerical modeling techniques. SWERA data products were developed by institutions with a long involvement in resource assessment activities and who have a demonstrated history of producing high-quality data through application of numerical modeling approaches. The SWERA renewable resource data are provided without charge with an aim to remove informational barriers to renewable energy development. Data are provided as monthly and annual averages at high spatial resolutions and in standardized GIS formats. This allows users to explore the renewable resource distribution across countries and seasons and the relationship between resource rich regions and existing infrastructure, both of which can be used for policy and planning purposes by governments and energy planners and developers.

More detailed, site-specific data are needed to design large renewable energy projects. Hourly data collected at a potential project site for a minimum of one year will provide a much more detailed characterization of the resource at that location, and additional

investigations into inter-annual variability can reveal the representativeness of the year of collected data.

There are other high-quality renewable resource data sets produced through numerical modeling that are not included in the SWERA archive, some of which may require the data be purchased. Some of these may also provide modeled hourly data, which can be used in project simulations to estimate economic feasibility in advance of collecting ground data.

3.3 How to find available SWERA products

3.3.1 Locating products

There are several ways to access SWERA products from the web site. Users can browse through all products of a given type or search for products by geography or renewable resource.

Locating products through the Home page

When visiting the SWERA website's home page, users can search for products based on the renewable resource using the icons in the main page.

By selecting the Solar, Wind, or TMY icons on the home page (figure 3) or by using the drop down menus at the top of all pages (figure 4) users are directed to pages describing the SWERA products available under each of these categories and search for products meeting their needs (figure 5).

Figure 3. Resource icons on SWERA home page.

Figure 4. Accessing the solar, wind, and TMY pages through the Using SWERA menu.

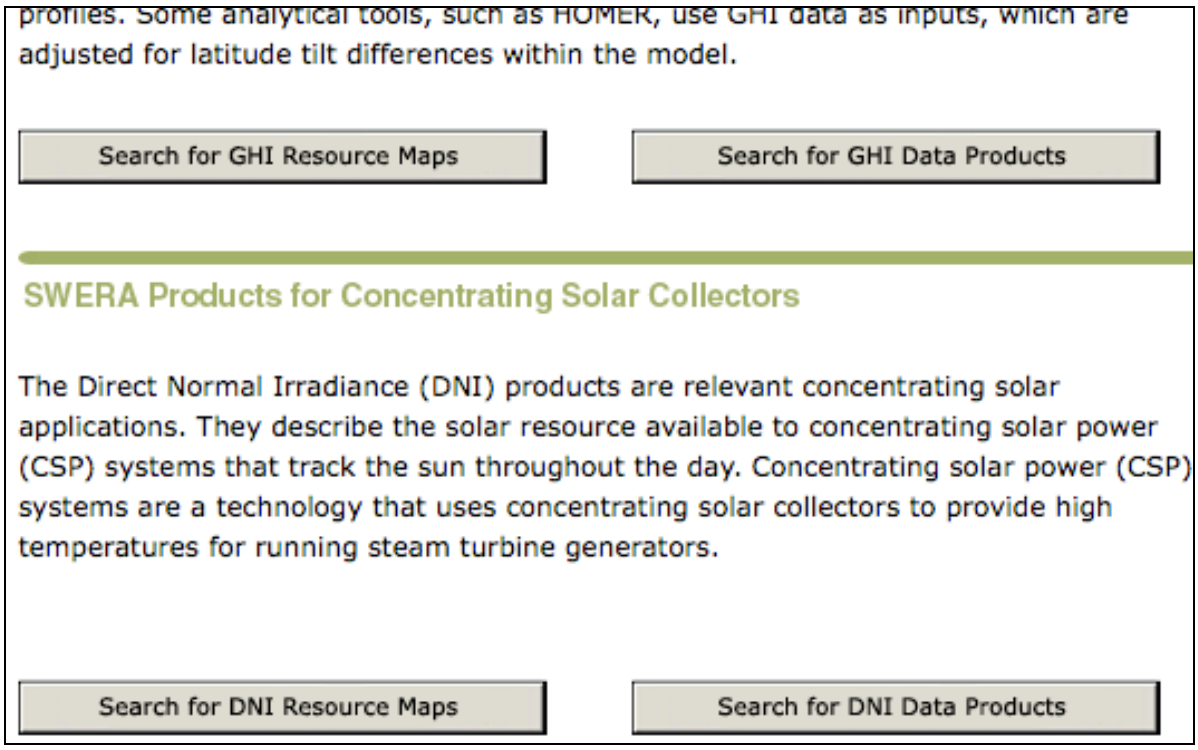


Figure 5. From the SWERA solar page, users can learn more about the products available and search for maps and data products.

When users choose to search for a specific set of products from the solar, wind, or TMY pages, they are then taken to a new page where all of the products fitting that description are listed. The product list will show a descriptive name, the geographic coverage area, the renewable energy category, the product type, and the date posted to the web site. Users can then filter the list based on geography, get more details on the products by selecting the link at the end of each row and then download the products to their computers (figure 6).

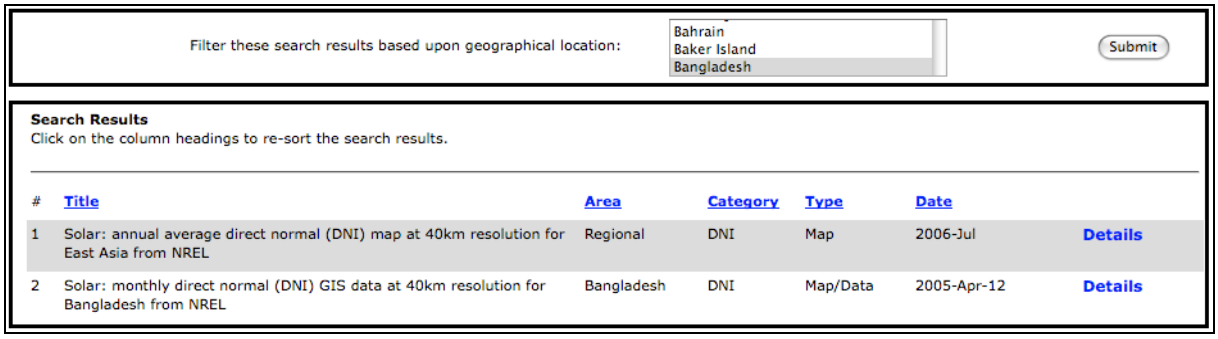


Figure 6. Results list after searching for SWERA DNI map products and applying a geographic filter for Bangladesh.

Locating products using SWERA's search feature

Users can also locate SWERA products using the search functionality accessed through the Product Search option in the SWERA menu bar (figure 7). Selecting this option leads

to a new page where users can search by product type, geographic region, or build their own search through the advanced search utility.

Figure 7. The SWERA menu bar with the Product Search option highlighted.

Using the search by product type allows users to view SWERA products for all geographic locations that are of a certain topical focus and format. For example, users can select to view all SWERA *wind* products in *data* format or all SWERA *solar DNI* products available as *maps* (figure 8).

Search By Product Type

Solar Tilt	Data	Maps	Documents
Solar DNI	Data	Maps	
Solar GHI	Data	Maps	
Wind	Data	Maps	Documents
Climate	Data		
Typical Meteorological Year	Data	Maps	
Geospatial Toolkits	Data	Data & Toolkits	

Figure 8. Searching for SWERA products by type.

Searching by geography allows users to view all SWERA products available for a certain region or country. Once the users select the geographic area of interest, a list of relevant SWERA products is returned that includes all available topical areas and formats. When a country is selected, the product list will include country-specific SWERA products, regional products that include the country of interest, and general documentation products that describe how SWERA data were developed. When a region is selected, the regional and documentation products will be listed along with all individual country products available for countries in that region.

The advanced search option allows the user to search for products by geography, energy topic, product type, and any combination of the three criteria (figure 9). When users first select the advanced search option, they are routed to a page where all SWERA products are listed. At the top of this page, users can narrow the product list by selecting options under geographic area, SWERA energy type, and product type. More than one option can be selected under each of these categories by holding the control key while selecting the multiple options. Once the user selects the desired options and clicks the select button, the list is narrowed to only show products meeting the selected criteria.

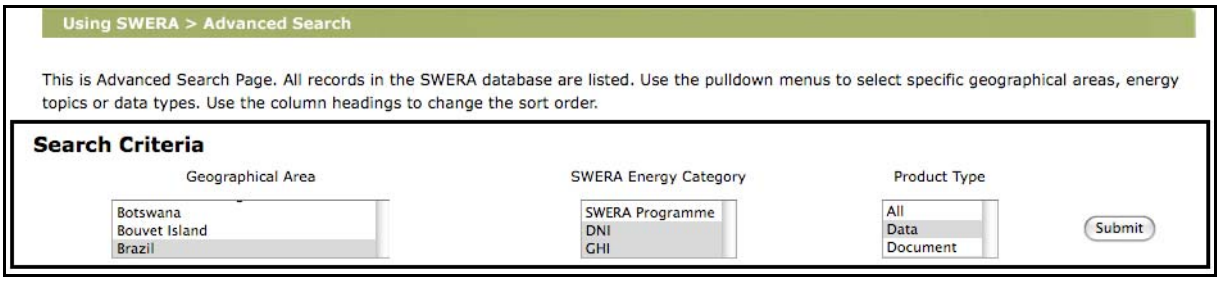


Figure 9. Using SWERA's advanced search option.

3.3.2 Accessing products

After users have specified their search criteria using one of the methods discussed above, a list of products meeting those criteria is returned (figure 10). This list shows the name, geographic area covered, energy category, product type, and date posted for each product.

Search Results
Click on the column headings to re-sort the search results.

#	Title	Area	Category	Type	Date	
1	Brazil Direct Normal Solar Radiation Model (10km) from INPE and LABSOLAR	Brazil	DNI	Data	2009-Aug-08	Details
2	Brazil Direct Normal Solar Radiation Model (40km) from INPE and LABSOLAR	Brazil	DNI	Data	2009-Aug	Details
3	Brazil Global Horizontal Solar Radiation Model (10km) from INPE	Brazil	GHI	Data	2009-Aug-08	Details
4	Brazil Global Horizontal Solar Radiation Model (40km) from INPE	Brazil	GHI	Data	2005-Aug-08	Details
5	Solar: monthly and annual average direct normal irradiance GIS data at one-degree resolution of the World from NASA/SSE	Regional	DNI	Data	2009-Mar	Details
6	Solar: monthly and annual average global horizontal irradiance GIS data at one-degree resolution of the World from NASA/SSE	Regional	GHI	Data	2009-Mar	Details
7	South America Global Horizontal SR Solar Model from INPE and LABSOLAR	Regional	GHI	Data	2009-Aug-05	Details

Figure 10. Product list returned after searching for SWERA GHI and DNI data for Brazil.

Users can click on the details link for each product, which will open a new page with additional information on the product. On the details page, users can access more detailed information or click to download the product. For some products, there are also options to view an image of the product before choosing to download or visit the website of the institution that developed the product. If users choose to download a product they are first asked to input some basic information about affiliation and planned use of the product.

3.4 How to use the Renewable energy Resource EXplorer (RREX)

When the RREX tool is opened via the SWERA web site, users are presented with a world map with topographic shading and no renewable resource data layers visible.

Users can zoom and pan to a location of interest by using the navigation controls in the upper left of the screen. The "+" and "-" will zoom in and out, respectively. Users can quickly zoom to a specific area on the map by holding the shift key on the keyboard and drawing a box with the mouse. Clicking on the globe icon between the symbols will return the map to the full global extent. Once zoomed in, clicking the arrows will allow

the user to pan from left to right and up and down. Users can also pan by holding down their left mouse button and dragging the map view in the direction desired.

Users can view summarized resource information for a location by clicking on that location on the map (figure 11). The green arrow that appears on the map shows the location selected, and the text appearing below the map shows the reference coordinates and the highest resolution data available for that particular location.

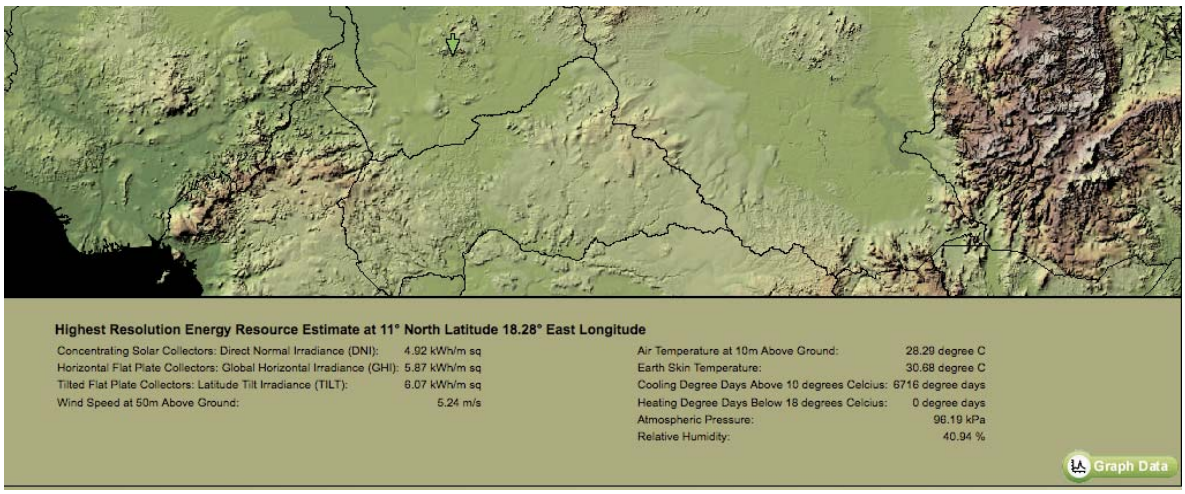


Figure 11. Accessing data through RREX: the location selected is indicated on the map with the green arrow, and the text below shows the reference coordinates and a summary of annual average data for the highest resolution resource data available.

Users can see what data sets are available for that location, including any time series information, by clicking the *Graph Data* button on the lower right of the screen. Selecting this option opens a new window with two data tabs (Renewable Energy and Climate) that users can toggle between at the top of the page (figure 12). The *Renewable Energy* tab allows users to view all of the solar and wind data available for the recently selected location through SWERA. With both windows open the user can click on different map locations and the graphs will be automatically updated.

Each graph displays resource data for a specific category of resource data, including Direct Normal Irradiance, Global Horizontal Irradiance, Latitude Tilt Irradiance, and Wind Speed at 50m Above Ground. Users can display or hide individual graphs by clicking on the label bar at the top of each graph. For each individual graph, the data layers available for that category are listed to the right of the graph. If the data layer is grayed out, that data source is not available for the location selected. All available data layers can be displayed or removed by checking or unchecking the boxes next to the layer name. The default view is to only display the highest resolution data available for a specific location. If no monthly data are available, the annual value is plotted for every month with the monthly points connected with a dashed line (instead of the solid line used when actual monthly values are shown). If monthly data are available, a user can click on a point on the graph and a map of the monthly data will be displayed below the graphs. The user can then step through the monthly maps by clicking on the monthly labels or by clicking play to see changes in the spatial distribution of the data throughout the year.

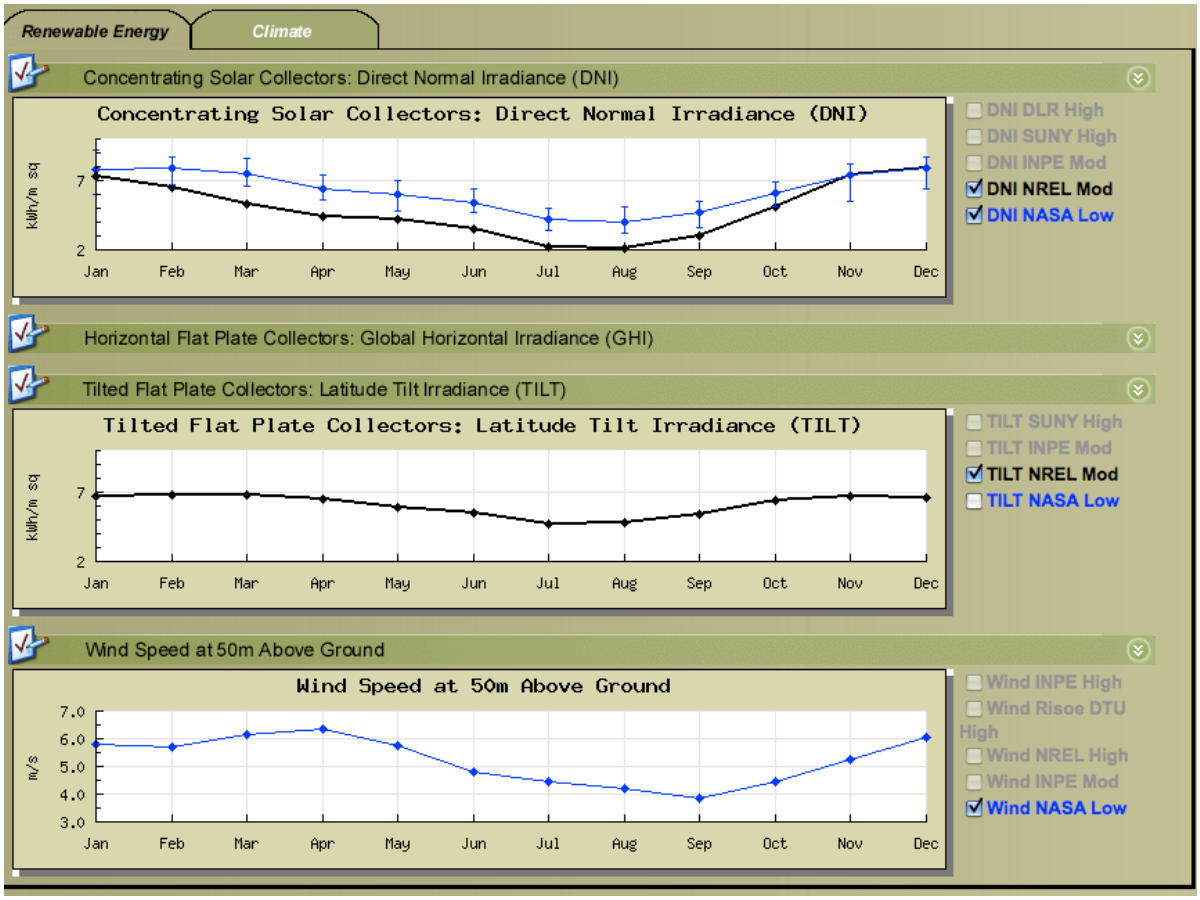


Figure 12. This figure shows the time series data accessed through RREX by using the *Graph Data* option on the main window. This image illustrates how users can display data from multiple sources by checking the boxes next to more than one data layer (DNI graph), how graphs can be hidden by clicking on the label bar (GHI), and how unavailable data layers are grayed out.

To the right of the graphs, users are given additional display and download options. Under *Display Options* is a drop-down menu, where users can select *Highest Resolution* or *All Available.* Selecting either of these options will refresh the page to reflect your selection on all maps. Note that if you have hidden some graphs, these will remain hidden when the page is refreshed; only the data displayed on the visible maps will change.

When users select the *Climate* tab at the top of the page, they are shown the monthly average temperature (air and earth skin), heating and cooling degree days, atmospheric pressure, and humidity for the location selected. Graphs and data layers can be hidden and displayed in the same way as is done on the *Renewable Energy* tab.

Under the *Download Data* section, users have a few different options to save the SWERA data to their computer. Users can download all selected layers in XML or CSV format. When users select one of these options all data layers with boxes checked on both the *Climate* and *Renewable Energy* tabs are downloaded.

RREX also provides users the opportunity to download GHI and wind data for use in the HOMER model. Note that the data layer must be selected and displayed on the graph before is appears on the list of options for HOMER download. Once users click on the data layer of interest for HOMER, the window displays the data in HOMER-ready in XML format. Users can then save this XML file for import into HOMER.

Users can also view mapped versions of available resource data through the main RREX page (figure 13). When users select the *Map View* tab to the right of the main map, all of the data layers available are listed in tree form. When users check the box next to a data category (e.g. Direct Normal Irradiance), all data available for that category is displayed on the map. The higher resolution data will be displayed on top of the lower resolution data when there is more than one data set available for a given country or region.

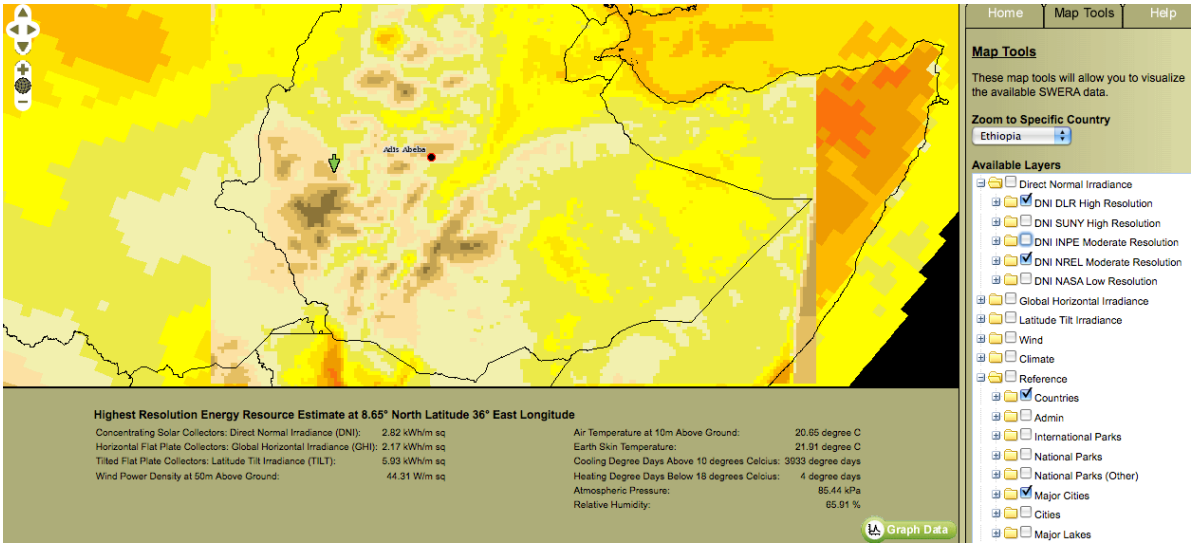


Figure 13. This screen capture shows the map view zoomed in on Ethiopia by using the drop-down menu in the Map Tools tab. There are two DNI data layers displayed, with the higher-resolution DLR data on top of the NREL moderate resolution data. The country boundary and major cities reference data layers are also displayed. Users can still click on the map (green arrow represents the selected location) to access point specific data, which is displayed in the panel below the map.

By clicking the "+" next to a data category the list of available data sources for that category are displayed. By checking and unchecking the boxes next to each data source, users can refine what data layers are displayed on the map. By clicking the "+" next to a data source, the legend for that data layer is displayed. Users can hide the legend by clicking the "-" next to the data layer.

For more information about individual data layers users can click on the data source name, which will open a pop-up window containing a brief description. Through that pop-up window, users will be provided a link that will take them to a SWERA page where all data layers meeting that description can be downloaded. The pop-up window can be closed by clicking on the "x" in the top right corner.

Users can zoom and pan while using Map Tools by using the navigation controls in the top left of the screen. If a specific country is of interest, users can zoom to that country

using the drop-down menu in the Map Tools menu to the right of the map. Users can also still access summary data for point locations by clicking on the map and access the more detailed time-series data by selecting the Graph Data option.

3.5 How to use the SWERA Geospatial Toolkits (GsTs)

The Geospatial Toolkits (GsTs) were initially developed under SWERA by NREL, and they have been enhanced and expanded since the SWERA pilot program. In addition to accessing these products through the SWERA web site, they can be accessed via the NREL web site: http://www.nrel.gov/international/geospatial_toolkits.html.

The GsTs are stand-alone applications combining GIS capabilities with data for a particular region or country. To use the GsT, users must first download the executable file (*.exe) for the region of interest. When the user double clicks on the downloaded file, the user is guided through a series of prompts as the GsT installs on the machine to identify the installation location. Once installed, the user can open the program from the location on their hard disk and use it to view the resource data for that region and run basic queries. For help with installation and use of the GsT, please refer to the Getting Started Guide, accessible through the NREL link above.

3.6 How to use HOMER

HOMER is a hybrid optimization model that was developed at NREL and is now licensed through HOMER Energy (http://www.homerenergy.com/). HOMER is a stand-alone model that can be installed and run on any PC, and there are various versions of HOMER to suit a range of user groups. For help in selecting which version of HOMER is best and for help with installation and use, please see HOMER Energy's software page for version information and a Getting Started Guide: http://www.homerenergy.com/software.asp.

3.7 How to use RETScreen

RETScreen was developed by Natural Resources Canada and allows users to analyze the energy production or savings, costs, emission impacts, and financial viability of various renewable energy and energy efficiency projects. RETScreen must be downloaded and installed on your personal computer for use. It is available in several languages and there are detailed training manuals available as well as periodic training courses. To download RETScreen and related training materials, please visit their web site at http://www.retscreen.net/.