UNITED NATIONS ENVIRONMENT PROGRAMME

PROJECT DOCUMENT SUMMARY

1.1 Title of Sub-Programme: Climate Change

1.2 Title of Project: Solar and Wind Energy Resource Assessment

1.3 Project number: GF/

1.4 Geographical Scope: Global (10)

1.5 Implementation: Internal DTIE with 20 supporting agencies

1.6 Duration of the Project: 36 months

Commencing: June 2001
Completion: July 2004

1.7 Cost of Project: (Expressed in thousands of US dollars, excluding PDF grant)

	2001	**2002**	**2003**	**2004**	**Total**	**%**
GEF Trust Fund	1,430	1,742	1,613	1,013	6,512	73
Collaborating Agencies (in kind)	418	836	836	418	2,508	28
	3,849	4,580	4,452	3,435	9,020	100

1.8 Project Summary

This project will provide solar and wind resource data and geographic information assessment tools to public and private sector executives who are involved in energy market development. It will demonstrate the use of these instruments in investment and policy decision making and build local capacities for their continuous use. The project will enable private investors and public policy makers to assess the technical, economic and environmental potential for large-scale investments in technologies that enable the exploitation of two increasingly important sources of renewable energy. During this pilot project, tools for analysis and use of resource information will be developed, a global archive and review mechanism will be initiated, regional/national solar and wind resource maps generated and national assessment demonstrations performed. The overall goal is to promote the integration of wind and solar alternatives in national and regional energy planning and sector restructuring as well as related policy making. The project will enable informed decision making and enhance the ability of participating governments to attract increased investor interest in renewable energy. Thirteen countries will be directly involved in the pilot stage of the project. Global and regional maps will be available to all developing countries.

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UNEP/GEF PROJECT BRIEF

Identifiers:

Project Number:
Project Name: **Solar and Wind Energy Resource Assessment**
Duration: **3 years**
Implementing Agency: UNEP
Executing Agency: UNEP/DTIE in collaboration with: National Renewable Energy Laboratory (US), Risø National Laboratory (Denmark), Tata Energy Research Institute (India), the National Institute for Space Research (Brazil), German Aerospace Center (Germany), Center for Renewable Energy Development (China), State University of New York (US) Renewable Energy Research Centre (Bangladesh), National Engineering Research and Development Centre (Sri Lanka), Centre for Energy Studies (Nepal), Ministry of Mines and Energy (Ghana), Ministry of Energy (Kenya),Ethiopian Energy Development Centre (Ethiopia), Energia y Minas (Guatemala), Ministerio del Ambiente y Recuros Naturales (Nicaragua), Ministra de Recursos Naturales y Ambiente (Honduras), Ministerio de Medio Ambiente y Recursos Naturales (El Salvador), Brazilian Wind Energy Centre (Brasil), Universidade Federal de Santa Catarina (Brazil), Agencia de Ciencia y Tecnologia (Cuba)
Requesting Countries: China, Bangladesh, Sri Lanka, Nepal, Ghana, Kenya, Cuba, Honduras, El Salvador, Nicaragua, Ethiopia, Brazil, Guatemala
Eligibility: All countries have ratified the UNFCCC and are eligible for GEF support
GEF Focal Area: **Climate Change**
GEF Programming Framework: **OP#6 -** Promoting the adoption of renewable energy by removing barriers and reducing implementation costs

3. Costs and Financing (Million$ US) : 9.320 (including PDF already executed)

GEF:	Project	: 6.512
	PDF	: 0.300
	Subtotal GEF	: 6.812
Co-financing:	NREL	: 1.164
	Risø	: 0.094
	TERI	: 0.060
	SUNY	: 0.236
	INPE	: 0.081
	DLR	: 0.152
	GTZ	: 0.100
	National Agencies	: 0.621
	Subtotal Cofinancing	: 2.508
	Total Project Cost	**: 9.320**

4. Associated Financing (Million US $): UNDP projects in China, Sri Lanka, Caribbean, Kenya, Brazil, World Bank projects in China, Nicaragua, AsDevBank in China (cost not estimated)

5. Operational Focal Point Endorsements: See Annex L

Nepal, Hari Prasad Regmi, Feb 15, 2001

Ghana, EPD Barnes, Jan 22, 2001

Guatemala, Dr. Juan de Dios Calle Schlesinger, Sept. 27, 2000

Ethiopia, Tewolde Berhan Gebre Egziabher, Nov. 23, 2000

Sri Lanka, BMS Batagoda, 26 January, 2001

El Salvador, Ana Maria Majano, 31 May, 2000

Cuba, Humberto Arango, 12 Sept. 2000

Honduras, Xiomara Gomez de Caballero, May 31, 2000

China, Jinlin Yang, Aug. 9, 2000

Nicaragua, Garcia Cantarero D., June 8, 2000

Kenya, B.O. K'Omudho, Sept. 18, 2000

Brazil, Sergio Sanginito Novaes da Silva, Nov. 1, 2000

Bangladesh, Md. Shawkat Ali, Oct. 13, 1999

6. IA Contact: Ahmed Djoghlaf, Executive Coordinator, UNEP/ GEF Nairobi

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List of Acronyms and Abbreviations

CSP	Concentrating Solar Power
CBEE	Brazilian Wind Energy Center, Brazil
CEPEL	Electric Power Research Center, Brazil
CPTEC	Center for Weather Forecasts and Climate Studies, Brazil
DLR	German Aerospace Center, Institute of Technical Thermodynamics
DTIE	UNEP Division for Technology, Industry and Economics
GEF	Global Environment Facility
GIS	Geographic information system
GRID	UNEP Global Resource Information Database
GTZ	German Agency for Technical Cooperation
INPE	National Institute for Space Research, Brazil
LABSOLAR	Laboratory for Solar Energy, Brazil
KAMM	Karlsruhe University Atmospheric Meso-scale Model
NASA/LaRC	U.S. National Aeronautics and Space Administration Langley Research Center
NREL	U.S. National Renewable Energy Laboratory
Risø	Risø National Laboratory, Denmark (also spelt Risoe)
SUNY	State University of New York
SWERA	Solar and Wind Energy Resource Assessment
TERI	Tata Energy Research Institute, India
TMY	Typical Meteorological Year
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme

Resource Information Format Definitions

Resource Atlas: Tabular resource information by geographic location. This information may be measured or estimated and while it is generally more detailed (time variations, directionality, etc.) it is for discrete locations.

Wind atlas: A wind atlas is a collection of regional wind climate descriptions on scales of 100 to 10,000 km that document the wind power potential. Regional wind climate/wind atlas data provides wind statistics and a directional wind rose that is generally valid for a surrounding region (~50 km).

Solar or Wind Maps: Maps provide spatial variation in the resource parameters as a graphic display.

Interpolated Maps: The simplest form is an interpolated map that uses atlas information and assumes linear variation of the resource parameters between locations. The global wind resource map by the Pacific Northwest Laboratory, 1980 is an example of an interpolated map although some adjustment of the linear interpolation was made to account for variations in terrain.

Pixelised Maps: Pixelised maps contain estimates of the resource parameters for discrete unit areas or pixels. These estimates may be derived from measurements for each pixel area (as with solar maps from satellite measurements) or derived from measurements at other locations using models of the resource parameters (such as the use of upper air wind velocity data sets of coarse resolution with a wind model and terrain data predicting surface wind velocity at a high resolution).

Combined Resource Information Format – GIS: Resource atlases and maps can be combined most easily and effectively in a Geographic Information System format. High resolution maps are most useful for siting larger energy facilities such as grid connected solar thermal electric generation facilities or wind farms. Medium resolution maps my provide useful additional information where they represent longer time periods (giving better long term performance estimates). Atlases provide the most detailed information and this tabular information can be integrated into a GIS as metadata such that it can be accessed by clicking on a map location.

BACKGROUND AND CONTEXT

1. Slowing and eventually reversing growth in global greenhouse gas emissions will require, amongst other initiatives, the large-scale use of renewable energy technologies for producing thermal energy, electricity, and hydrogen fuel. The Global Environment Facility is committed to supporting the use of renewable energy technologies on an unprecedented scale throughout the world. Over the next several decades large-scale applications of wind electric and solar electric technologies could grow to several hundred thousand megawatts. By 2008 the European Wind Energy Association expects 70,000 MWe of wind electric capacity to be in place globally. The great majority is expected in Europe and the United States, *despite of the enormous and growing potential in the developing world.* Similarly, the potential applications of photovoltaic technologies are expected to continue to grow robustly (>30%/year), with market breakthroughs as installed system prices fall below ca. US$ 4 – 6 per watt over the coming decade. Solar thermal power plants may also achieve large-scale commercial "breakthrough" with the support of IFC/World Bank/GEF initiatives. The KfW, in concert with UNEP/DTIE, is exploring the potentials for decentralized grid-connected PV plants in conjunction with hydro plants in developing countries around the world that could lead to rapid growth in PV applications Taking into account that resource information is often not available in developing country markets resource assessment need to be redirected to developing countries to accelerate these investment opportunities.

2. Investment in wide-scale intensive application of these technologies in developing countries is inhibited by the lack of adequate solar and wind resource data and by the lack of tools to evaluate these data for energy planning. A critical parameter in the costing of solar and wind energy development is the proximity of possible generation locations to load centres and electricity grid stations. The surface topology has a major influence on micro-climate resulting in highly variable wind resources and significantly variable solar resources over small areas. Without reliable resource information, potential investors tend to avoid the risk of wind or solar project development activities. Main stream investors, venture capital firms and independent power producers are not aware of viable renewable options.

3. The project will influence investment decisions by promoting alternate business scenarios beyond those an energy developer might take on his own, working directly with banks and developers to overcome informational barriers in EE/RET financing. Through targeted appraisals of solar and wind technologies the project will increase investors' familiarity with EE/RET investments. Knowledge and perception barriers, once removed, are unlikely to return.

4. Information on the potential for solar and wind energy can also influence policy and national planning. Although long term average costs of solar or wind may be higher than for hydropower, diversification of energy supply will become more important as climate change impacts cause droughts and endanger the availability of hydro resources (as experienced recently in Kenya, Ghana, and other African countries). Security of supply could justify increased buying tariffs for independent power producers. The reliability of the solar and wind energy resources over time, and phase relationship of these resources relative to other fluctuating resources, can therefore be important. Without accessible, high quality information solar and wind energy development opportunities for enhancing supply diversity and security will be missed.

CURRENT BASELINE ACTIVITIES:

5. Availability of reliable and easily useable resource data is essential for government and industry to identify in-country power generation potential from these options and to act on that knowledge. Yet most developing countries lack such reliable, sufficiently detailed and easily used solar and wind energy resource data. This lack is a *primary obstacle to both public-sector and private-sector investments in renewable energy applications in most of the developing world, including renewable energy projects and programs supported by the GEF*. This project addresses that obstacle, in response to Operational Programme #6 – Promoting the Adoption of Renewable Energy by Removing Barriers and Reducing Implementation Costs.

6. The barrier removal opportunity for this project was identified through the experiences of some developing countries in considering the requirements for incorporating *large-scale* use of solar and wind energy systems in national energy development planning. Developing such resources responds to their commitments and interests as parties to the UN Framework Convention on Climate Change (UNFCCC), and to many countries' national interests (and energy development plans) in diversification of their energy mix, expanding domestic energy production, and diminishing the environmental burdens of energy supply. Lack of adequate renewable energy resource information is blunting their efforts to use these resources. When the information becomes available, important new renewable energy development programs can be initiated and existing programs expanded. Examples of assessment projects and their impact are described in Annex D: Incremental Cost and Global Environmental Benefits of Improved Resource Information. Annex E: Baseline Solar & Wind Energy Resource Data & Information Development Activities describes baseline activities within each of the pilot countries.

7. In the case of solar, very few weather stations make actual pyranometer solar measurements, so solar information has to be derived from human-based cloud cover observations, or simple instruments that record only the number of direct sunshine hours in a day. Available global solar resolution data[1] is lower resolution and can be improved for microclimates. In the case of wind, the measurements can often be blocked by nearby obstacles (encroaching construction and trees), resulting in unrepresentatively low readings. Furthermore, in many countries, areas with the best wind resource have no measurements at all, this leaving with the impression that the total wind resource availability is much lower than is actually the case. The current global low resolution wind map is considered inadequate for energy assessment in most regions of the world.[2] In addition, for both solar and wind measurements, many countries do not have the financial resources to maintain and properly calibrate the measuring equipment, further contributing to the uncertainty of resource assessments using these data. Due to mechanical component deterioration in anemometers, errors in wind speed are systematically biased to under representation of wind

1. The U.S. National Aeronautics and Space Administration (NASA), Langley Research Center (LaRC) has developed a world-wide surface solar energy data set as part of its activities with the World Climate Research Program. The data set provides daily and monthly global horizontal solar resource data on 280x280 km cells for a four-year period. The data are completely derived from weather satellite data, although validation studies using ground-based measurements have been conducted. This data set is readily accessible through the Internet, and on CD-ROM available from NASA/LaRC.

[2] A world-wide wind resource map was prepared by the U.S. Pacific Northwest National Laboratory in the early 1980s. The low resolution (100 km by 100 km) of this map prevents it from being useful in identifying regions likely to have commercially significant wind energy resources

speed. Data can be difficult to access and is often not in digitized format. Since meteorological systematic tracking is considered a national baseline responsibility, measurements themselves are not proposed for GEF funding in this project.

8. UNEP operates the Global Resource Information Database (GRID) as a facility for gathering, archiving and making information accessible. Information covers a broad range of environmental issues and carries information from many of sources. Solar and wind energy assessment information is not currently carried. As solar and wind energy information will be useful for studies phenomena like surface moisture evaporation rates, carrying this data will be consistent with GRID's long term mandate. This facility combined with UNEP, Division for Technology Industry and Economics with focussed efforts on renewable energy and industry support services will provide a sustainable solar and wind energy resource information service.

9. See Annex E: Baseline Solar & Wind Energy Resource Data & Information Development Activities

RATIONALE AND OBJECTIVES

10. The global environmental objective of the pilot project proposed here is to make available and accessible reliable, high resolution solar and wind energy resource information, thereby removing a significant barrier to widespread use of clean solar and wind technologies. The project will transform the ability of developing countries to assess the technical, economic, and environmental potential for broad scale investments in solar and wind facilities, and amplify their ability to attract private and public sector investments. The goal is to support more informed decision-making, science-and-technology based policy, and increased investor interest in renewable energy. UNEP proposes to engage the solar and wind energy communities (industry, investors, researchers, and government agencies) through a low cost network by which information is continuously shared so that solar and wind energy planning decisions can be made progressively and expeditiously.

11. Removing the key information barriers to large scale deployment of solar and wind energy technologies in developing countries can be achieved by improving the quality and accessibility of renewable energy resource data and provision of planning support tools. The value of diversified energy supply and the potential for economic development can not be analysed without sound information. In addition to the assembly of global information, countries will be targeted for pilot demonstration of high-resolution mapping and assessment of national solar and wind energy development potential. National studies using the tools and other information will indicate the policy opportunities and potential investment impact of the assessments and provide a further indicator of the global potential for wind and solar energy.

12. The techniques for mapping offered through this project will be complementary to parallel measurement programs and provide targeting of measurement activities for best results. The overall cost of preinvestment activities are lowered through the techniques offered. Computer mapping of solar and wind potential is an incremental activity to most developing country activities and technology transfer would not generally be cost efficient in the near future. Building on the information provided during project development, the initial technical reviews will focus

on how technical transfer can incrementally build the capability to make national contributions to the project goals and leave a sustainable core capacity for further work.

13. Following the STAP recommendation that renewable energy technology assessments be done, the concept paper "Wind Resource Assessment: State-of-the-Art Technology Applications and Technology Transfer in Latin America and Asia" was submitted and approved for pipeline entry January, 1998. The project will integrate both solar and wind into a consistent GIS data base platform with analysis tools. UNEP will build on its industry and energy clearinghouse function to fill information gaps and also build on UNEP activities in global resource assessments and tool development.

14. The outcomes of SWERA will be:

- Reduced uncertainties associated with investment and development decisions for solar and wind projects. This in turn will decrease uncertainties in the design, cost, and performance of solar and wind systems, and should increase investor confidence, and confidence of key stakeholders, such as government agencies responsible for facilitating clean energy development.
- Increased awareness by key stakeholders and decision makers of the solar and wind resources and the relevance of the resource information to the development and deployment of various solar and wind technologies, (existence of potential resource, inclusion of solar and wind energy technologies in energy planning)
- Consistent, reliable, verifiable, and accessible global data sets for international and in-country investors and other stakeholders
- Increased capacity for making solar and wind energy plans on the local, provincial, national, and regional levels. The availability of the solar and wind resource data and training in the use of the tools to make use of the data will facilitate better planning for solar and/or wind energy development. In some countries, large-area high-resolution wind and solar resource mapping is expected to reveal far larger commercial wind and solar project development potential than currently thought possible. In order to demonstrate the outputs of SWERA, nationally executed assessments of the potential for solar and wind development will be performed.

ACTIVITY COMPONENT 1: SOLAR RESOURCE ASSESSMENT

ACTIVITY 1.1 SOLAR METHODOLOGY AND INFORMATION REVIEW PANEL

15. In view of the wide range of capability found among the participating countries of the project, it is expected that a wide range of existing information on solar energy resources and assessment capacity will be available. A solar review committee will be established to review available information and assessment capacity from each participating country. The review committee will include relevant country partner experts, solar experts from SWERA, and independent experts. Existing country data will also serve as validation or comparison data sets and as background reference data.

16. An output of this review activity will be technical reviews of all data sets and the associated methods. These reviews will define how the SWERA activities will add value to existing solar resource information and the reviews will be available to support informed selection and use of existing data in the global archive. UNEP will closely monitor and approve the selection of

assessment activities in order to ensure targeting of best opportunities for global benefits and avoiding duplication with national or other agency actifities.

Activity 1.2 Gather Relevant Meteorological Data from National or other Archives

17. Country partners will gather relevant in-country data sets to support the solar assessment process. Such data sets include solar validation data and meteorological data used as input to the models (such as surface temperature and relative humidity, aerosol optical depth). Of particular value will be the identification of and access to specialized data sets that are not normally available as part of routine weather station observations. For example, data collected for research purposes, data available through universities or private parties, and data collected by other government agencies such as agricultural offices can be useful to the solar assessments.

18. An output of this activity will be the compilation of data sets and reports that the country partners can use in conjunction with the SWERA team for the solar assessment work. Country partner roles will also include the reprocessing of selected data sets to be used into the solar assessment methodologies and incorporated into the final data archive (TMY, validation data).

Activity 1.3 Develop Solar Resource Maps

19. A global *coarse resolution* solar resource map is being developed by the NASA/LaRC, and is available to this project. NASA/LaRC global coarse resolution $1^o x1^o$ climatological data set (available regionally) This map, to be completed in the latter half of 2001, provides global horizontal and diffuse solar resource data, using two different models, for the period July 1983 – November 1995. The database will include 3-hourly time series, daily, and monthly average values for each 1^o x1^o grid cell. An earlier version of this database, which will also be on 1^o x1^o grid cells based on an interpretation of data originally developed on 280 km by 280 km grid cells, will be available by the end of 2000.

20. *Medium resolution* (approx. 40 km x 40 km) climatological solar resource data sets, comprising monthly average daily total global horizontal, direct normal, and diffuse solar resource elements, will be developed for four major regions of the world: Mexico/Central America/Caribbean, South America, Africa, and South and southeast Asia (including China). Tools to calculate the resource for various collector orientations will be included in these databases.

21. *High resolution* (approx. 0.05^o to 0.15^o, 1-3 hourly) site/time specific solar resource datasets derived from geostationary satellite data will be developed to include targeted countries and regions in each of the four areas defined above.

Activity 1.4 Generate Time-Series Data

22. Typical Meteorological Year datasets will be developed from selected ground based three-hourly observations of cloud cover data collected over a period of 20-years or more for up to 100 sites, representing 6-10 sites in each targeted country. SWERA will work with the regional collaborators and the country partners to build the capacity for the country agencies to perform these calculations themselves.

Activity 1.5 Relate short-term satellite-derived time series to long-term ground-based time series

23. Existing tools and software will be configured and made available within the GIS tools of this project to relate time series data from the shorter-term satellite-derived model datasets, to the longer-term surface-derived data sets, so that TMY data can be adjusted to any grid cell available from the satellite data. These tools will be developed by members of the SWERA team and will work with the country partners to assure each country has the ability to use these tools and data sets.

Activity 1.6 Conduct Cross-Model Comparisons and Validation Studies

24. Cross-model comparisons among the results of the various methodologies identified above will be conducted to establish uncertainty limits for the model results. Validation studies, using existing ground data sets obtained from the country partners, will also be used to validate the various modeling approaches, and establish further information on the uncertainty of the model results. These studies will be enhanced by co-financing from the sponsoring organizations of the participating agencies. For example, a cross-model comparison of NREL's CSR model and INPE-LABSOLAR's BRASIL-SR satellite-derived solar model will be conducted in climatologically specific regions of Brazil South America, so that the results of the two modeling approaches can be used to define the uncertainty limits of their outputs, and to establish the relative performance of BRASIL-SR region-specific model to the global dataset developed from the CSR model. Results of these studies will be posted with the final SWERA data archive. Co-financing from the host organizations for this activity is anticipated.

Expected Results: Solar Resource Assessment

25. At the end of the SWERA pilot project the regional maps with improved solar resource information will be available to over 100 countries. Regional wind maps will also cover more than the participating target countries.

26. All participating countries will have:

- access to enhanced solar resource maps and expanded databases including national validation results and expanded time series information.
- the capacity to use the data in an effective manner to facilitate solar technology investment.
- understanding of how the resource data are developed
- improved ability to undertake measurement programs for further validation data as well as site-specific pre-feasibility studies

ACTIVITY COMPONENT 2: WIND RESOURCE ASSESSMENT

27. This component contains activities to remove information barriers on wind resources, expedite the deployment of wind technologies in the targeted countries. Although the situation varies between countries, the main barrier found in most of the countries is the lack of quality high-resolution wind resource maps and data that can be used to design and deploy a wide variety of wind technologies. Another barrier is that many countries lack the capacity themselves to develop this information. The wind resource products proposed for this project will take advantage of the research and development of sophisticated models, investment in advanced hardware and software technology, and access to expensive meteorological data sets. The per square kilometer cost of model generated maps varies by a factor of 10 with the size of the area

mapped due to the high cost of setting up the input data. Mapping of multiple countries is by far most cost effective. Hence, depending on the country capacity, the main barriers found range from either the lack of capacity for developing high-resolution wind resource maps, and/or the lack of capacity for effectively using these data if they were available.

Activity 2.1 Review of Existing Wind Surveys and Assessment Methodologies

28. In view of the wide range of capability found among the participating countries of the project, it is expected that a wide range of existing information and assessment capacity on wind energy resources will also be available. In this task, a wind review committee will be established to review available information methods and assessment capacity in each country. The review will include relevant country partner experts, wind experts from SWERA, and independent experts. The purpose of the review is to identify the wind resource, assessment capacity and related information already available to the country or region. This will form a baseline for the project. A selection from the existing country data will serve as validation data sets and as the reference data for interannual, diurnal and seasonal variability. Areas of interest for additional analysis using a mesoscale model will also be identified. UNEP will closely monitor and approve the selection of assessment activities in order to ensure targeting of best opportunities for global benefits and avoiding duplication with national or other agency activities.

29. An output of this review project will be technical reviews of all data sets and methodologies used. These reviews will be available to support informed selection and use of existing data, and to define how the SWERA activities add value to existing information. In an effort to build up analytical and data processing capability in partner countries, models and methodologies used to produce the wind map/atlas will be documented and made available through the SWERA archive.

Activity 2.2 Gather Existing Relevant Wind Data

30. Country partners will work with the SWERA team to assist in gathering relevant in-country data sets to support the wind assessment process. This includes the identification of existing wind data available from meteorological agencies and other sources. The different types of data to be identified include data collected from surface stations (i.e., ground-based measurements), upper-air stations (i.e., weather-balloon measurements), and marine data where available (i.e., ships, buoys). Data identified by in-country partners will be compared to data that are available from SWERA through its global datasets selected in-country data that are supplementary obtained for use in the assessment.

31. An output of this activity will be the compilation of data sets and reports that the country partners can use in conjunction with the SWERA team for the wind assessment work. Country partner roles may also include the reprocessing of data sets (such as supplementary weather balloon data) so that they can be input to the computer wind assessment methodologies.

Activity 2.3 Process Data Sets and Perform Critical Analysis of Data Quality

32. The SWERA team will collaborate with the country partners on the methods to be used for processing and analysing the various model input data sets. The SWERA team will share processed summaries of data from global data sets (e.g. DATSAV2) with country partners who will assist with the analysis of the data quality. Qualified regional or national experts will process

their in-country data sets, with guidance from the SWERA team to facilitate the use and integration of these data with the models.

33. The final critical analysis of the data to select the best and most reliable data for developing meteorological inputs to the models will be made by the SWERA team with in country assistance, particularly where qualified experts are available.

Activity 2.4 Adjustment of Surface Observations using WAsP methods

34. Country partners will be trained by SWERA technical support on the use and application of a highly localised method (WAsP) for adjusting ground measurement data and developing time-based information. The training and technical assistance will be through the regional institutions where appropriate. The country partners will apply these methods to selected data for use in verification of computer-generated wind maps and expansion of the assessment information to include variations over time.

Activity 2.5 Generate High-Resolution Wind Maps

35. For countries/regions identified, NREL's empirical/analytical model will be used to generate high-resolution annual average wind maps at 1-km resolution. It is anticipated that the mapping will be carried out for 5 to 8 regional blocks and include as many demonstration countries as possible. The KAMM mesoscale model would be run, especially for channeled wind corridors, and the results made available separately and as recombined with the empirical/analytical model data. Other models and methods will be considered where a cost/benefit advantage exists.

Activity 2.6 Prepare Wind Atlas

36. The preparation of the wind atlas document (non-map, meta-data stored information including interpretation of the wind maps and summaries of the salient wind characteristics) will largely be the responsibility of the country partners. Country agencies will provide the data such as the hourly time-series data and with technical support, prepare the summaries, graphical output of the data, and outputs of selected data sets with inter-annual, monthly, and diurnal variations for the meta-data sets in the global archive.

Activitiy 2.7 Conduct Cross-Model Comparisons and Validation Studies

37. For specific areas where feasible, cross-model comparisons among the results of the various methodologies will be conducted to establish uncertainty limits or confidence levels for the model results. For example, the NREL model and KAMM will be compared with the MM5 mesoscale model used by the Brazilian Center for Wind Energy (CBEE). Validation studies, using existing ground data sets obtained from the country partners, will also be used to gain confidence in the modeling approaches, and establish further information on the uncertainty of the model results.

Expected Results: Wind Resource Assessment

38. It is expected that at the end of the project participating countries will have:

· access to high-resolution wind resource maps and databases that will support planning for the deployment of a large range of wind technologies, from large utility-scale to small off-grid applications, water pumping, etc.

· the capacity to use the wind data in an effective manner to facilitate wind technology investment.

· an understanding how the mapped resource data was developed;

· enhanced capacity to undertake wind measurement programs to provide validation data for the assessments as well as site-specific studies for pre-feasibility;
· where mapping in blocks of small countries is done, the information will be made available for all the area in the mapped block although the national activities would not be executed in all countries within the pilot project. Mapping of countries and areas will be optimized within available resources.

ACTIVITY COMPONENT 3: INTEGRATION WITH GEOGRAPHIC INFORMATION SYSTEM (GIS)

39. A Geographic Information System (GIS) is the combination of hardware, software, data, and expertise used to create, modify, evaluate and analyze spatial or geographically referenced information in digital format. GIS data are comprised of two components: spatial features and attributes. The spatial features are elements that can be shown on a map. They include roads, rivers, population density, electric transmission corridors, meteorological stations, and the wind or solar resource distribution. The attributes are the associated information such as land ownership and use (designations such as forest, agriculture, park, etc), temperature, wind speed and solar radiation values. The combination of both a computerized map and a database within the same system facilitates planning and decision making.

40. This project will contribute to removing information barriers by integrating the solar and wind resource assessment products into a GIS format. Additionally, the SWERA project will provide an easy-to-use GIS Toolkit that supplements these data products, and is targeted specifically to organizations and individuals that lack GIS capability. Despite the growing presence of GIS throughout the world, it is often not used to facilitate renewable energy project deployment. It is noted that the full set of relevant information will include data sets already available from other agencies such as USGS, NASA, and GRID centres. Unless the information has been modified or adjusted, the most effective means of providing access is expected to be through pointers or web site links to the original source.

Activity 3.1 Develop standard GIS datasets

41. Geospatial Database Development. Geospatial datasets will be developed from the results of the solar and wind resource assessment activities. These datasets will be in a standard format, allowing for easy importation into commercial GIS software packages. These datasets will also be included within the GIS Toolkit and project archive sites for distribution. The resolution of these datasets will vary according to the resource assessment methodology used. These datasets will include the spatial representation of the resource and the associated attributes (tabular information).

42. *Metadata Development.* The documentation for the GIS datasets will be comprised of metadata to the International Standardisation Organisation standard. Metadata are “data about data” and include information about the data sets’ identification, quality, organization, spatial reference, entity and attributes, distribution and reference. This information facilitates informed use of the data and allows searches to be conducted through a GIS Clearinghouse.

43. *Conversion and Integration of Selected Data Sets into GIS format.* Additional data sets to be included in the archive and GIS Toolkit will support the analytical functions that can be performed within a GIS. These will include terrain, population information, administrative

boundaries, and when available in the public domain land use, load centers, transportation and transmission corridors. Finally, the data and associated information from ground based measurements and the qualifying information on data sources and limitations will be integrated with the GIS data.

Activity 3.2 Develop GIS Toolkit

44. A GIS Toolkit will be adapted from currently available GIS technology for widespread distribution. Interested parties will have access to the resource assessment data products in a format that allows for visualization and simple analysis with neither specialized software nor GIS expertise required. The GIS Toolkit will be a standalone product for use on most personal computers. The Toolkit will be distributed via CD-ROM. All toolkits will include the geospatial solar and wind resource data along with selected GIS datasets of topography, population and land use for that area. Additional datasets will be included on a per-country basis, if these databases exist in the proper format, are available in the public domain, and can be obtained at nominal cost. Regional agencies will be able to offer expanded customization services to agencies wanting to pay for additional capabilities or privately held information.

45. *SWERA Graphical User Interface*. A graphical user interface (GUI) will be developed to serve as the "front end" to the GIS Toolkit. This interface will be easy to use, will include on-line help, and will enable the user to access the program and associated data, and create graphical output. The programming environment will take advantage of object-oriented programming capabilities offered by several GIS vendors. A programming environment will be selected after careful evaluation of the options. The evaluation will include a consideration of the common GIS platforms in use throughout the world, the evolutionary nature of GIS programming and technology, and the specific needs of this project. This will ensure compatibility with the other project GIS data products to help ensure the long-term viability of the GIS Toolkit.

46. *Integration of appropriate geospatial databases from the SWERA GIS.* The successful analysis of geographically distributed phenomena requires appropriate geospatial databases. In addition to renewable energy resources and power generation and energy production potential for solar and wind technologies, the toolkit will incorporate existing GIS databases for topography, land use, and population density. Additional public domain data sets may be included at the recommendation of the regional and in-country partners, provided that these datasets exist, are readily available at nominal cost, and that there are no restrictions to their use.

47. *Algorithms and routines for the GIS Toolkit.* A subset of standard geospatial operations that are commonly performed within a GIS will be developed for the tool kit. These will initially be limited to overlay and proximity. Overlay operations will allow examination of resource related information with other factors that share a common geographic area. An example of an overlay operation would be the identification of areas where optimum solar energy resource intersects optimum economic conditions. Proximity operations will allow the user to measure how far apart two or more features are. An example of a proximity operation would be determining the distance from a load center to the nearest useable wind resource area.

48. *User Manual and Training Materials for distribution with the GIS Toolkit.* The success of this project will depend on the proper distribution and usage mechanisms being developed and

implemented. Selected individuals within the regional and in-country partner organizations will be trained on the use of the Toolkit. These individuals will then be available for continued or expanded training and user support with additional distributions of the Toolkit.

Activity 3.3 Needs assessment for in-country partners

49. The needs of in-country partners will be assessed based on their ability to implement the GIS component of this project. The amount and type of incremental capacity building with the in-country partners will take into account the environment in which current GIS capability resides, the existence and availability of databases, the capability to provide customer support and training, and finally, GIS infrastructure maintenance and sustainability. A regional collaborative agency will provide any of these services should an in-country partner with adequate capacity not be available. The in-country or regional partner will work in close collaboration with the SWERA Team to perform the necessary GIS related activities. Subject to needs and availability, these activities could include data compilation and integration, establishing a local data archive and dissemination facility, accessing databases for inclusion in the project, or training other national energy, wind and solar specialists. UNEP will closely monitor and approve the selection of assessment activities in order to ensure targeting of best opportunities for global benefits and avoiding duplication with national or other agency actifities.

Activity 3.4 Establish global archive

50. A global archive of solar and wind information with reference data sets and technical reviews supporting informed use will be established. UNEP/GRID facility will design the archive and dissemination activities to be replicated by regional/in-country partners. The standard, public domain products generated by the SWERA project will be freely accessible by international investors, agencies, and developers. The global archive will contain, or link to, existing data sets for world wide low resolution solar irradiance, population density, topography, land use and other wind or solar assessments, as available, from other organizations such as the World Bank, UNDP or GTZ. The products will include the solar and wind resource assessment maps, related data sets, and accompanying documentation. Additional archival locations and dissemination activities will be established during the project by regional or country collaborators to contain more country specific data. More country specific data sets (ie. electricity grid) will be under the control of the participating country, with dissemination activities taking place accordingly.

51. The technical review services are described elsewhere in this document. The reports generated by the technical review will be incorporated into the global archive. The global archive will include:

- Standard GIS data sets representing wind resources with supporting documentation
- Standard GIS data sets representing solar resources with supporting documentation
- Accompanying meta-data and data sets for wind and solar including TMY's, time series, etc
- Standard set of GIS data sets for topography, land use and population density
- Reports detailing technical review activities and findings
- Links to web sites that are pertinent to this project, such as the international, regional and country sites, GEF focal points or their designated agencies, the GIS Toolkit, and other UNEP/GRID sites

52. UNEP/GRID will develop an Internet world-wide-web site. This site will house the archive, act as a clearinghouse for searches, and disseminate products across the Internet. All inquiries and special data or service requests will be automatically directed to the SWERA team websites for processing. Regional and country centers will distribute products by offering CD-ROMs, Internet distribution, or other means. The regional and national partners will work in close collaboration with the SWERA team to perform the necessary integration, conversion, and dissemination activities.

ACTIVITY COMPONENT 4: NATIONAL APPLICATION OF THE SWERA TOOLS AND INFORMATION

53. Case studies in the utilization of SWERA tools in energy planning will demonstrate the potential for support to planning and development. The advantages of the information and tools leading to better targeted and more effective preinvestment resources, more accurate techno-economical analysis leading to realistic cost-benefit projections, framing specific policies and financial incentives to attract private sector investment, and energy development policies. This activity will enhance existing activities by other agencies where they are operating and the tools further delivered through the UNEP Sustainable Technology Advisory Network.

54. These products (and data) can be effectively used in national energy planning case studies exercises in the estimation of exploitable wind/solar resource potential under various scenarios, identification of potential regions of interest within the country and matching of resource availability with needs of population centres. The estimation of share of unserved energy demands that could be met by wind/solar energy in energy deficit pockets/regions can also be made. Other relevant analyses depending on available national data for electric grid lines, roads, etc. would also be included. The information can be marketed directly to investors who may not otherwise be reached.

Activity 4.1 Alternative business development scenarios in energy supply

55. This activity will demonstrate the outcomes of SWERA by developing and presenting solar and wind energy investment opportunities to investors. Marketing and outreach activity will require special efforts to reach investment decision-makers in venture capital companies, independent power producers, and utilities.

56. To create the business scenarios, information from other sources will need to be assembled. Drawing on existing national activities and GHG inventories, a number of demand growth scenarios would be selected. These will include national development plans. The work will consist of a review of available projections and selection of a few representative scenarios as opposed to a full mitigation analysis study. A nationally oriented technology mix will be identified that is a marketable to potential investors. This will include efficiency factors, nominal line loss characteristics, new load assumptions as required to convert the solar and wind energy resource data into usable potentials. Benchmark technologies will also be used for comparison purposes.

57. For participating countries, national stakeholders and particularly energy planners (including electrical utilities) will use the energy demand projections, solar and wind resource data, and engineering estimates of potential solar and wind based energy production as input to development of long term solar and wind development scenarios. These alternate business

development scenarios can demonstrate the long term strategic potential of renewables, and serve as a basis for estimating GHG emission reduction potentials. Insights gathered from such exercises can stimulate policy initiatives designed to attract public and private investment in renewable energy projects.

Activity 4.2 Marketing and presentation of the alternative energy development projections to investors

58. The project will influence investment decisions by promoting alternative scenarios to business-as-usual investment especially in fossil fuel power plant. SWERA will present these scenarios directly to banks, financiers and developers to overcome informational barriers in solar and wind projects development for financing.

59. The various dissemination formats will include, limited hardcopy maps and reports, web-based access to information, CDROM information only, and CDROM information with user friendly tools. The core solar and wind information will be housed in the global archive (described in Activity Component 4), however, the collaborating agencies, with backup from INPE, TERI will be able to customise and modify the auxiliary data (electric grid lines etc) and provide customised services and products to regional clients. Confidentiality of auxiliary data will be negotiated in respect of national requirements and proprietary rights. New web technology, such as ArcIMS and ArcSDE, is changing how data is archived and shared, and how disseminators interact with expert users and regional centers, particularly those with access to high speed internet. The new technologies will significantly assist the regional agencies and commercial investor's ability to do value-added marketing based on the core data. Within the limited funds of this pilot project, the SWERA products will be promoted to investors and policy-makers.

60. Expected results are:

- a demonstration of the value of the assessment activities
- an indication of the potential for increased estimates of the global potential for solar and wind energy utilisation.
- investment and policy changes

ACTIVITY COMPONENT 5. MANAGEMENT AND COORDINATION

Activity 5.1 Coordination of project activities

61. UNEP/DTIE will coordinate the project with regional assistance from INPE and TERI as required. The Steering Committee will include World Bank, UNDP and other cofinanciers as appropriate to coordinate activities.

62. During the pilot project, TERI and INPE will provide services to countries in their regions as needed. Where appropriate, they can coordinate the activities among national partners and develop the technical capability; after SWERA to ensure that SWERA products are effectively and efficiently utilized to achieve accelerated and continued deployment of solar and wind energy systems.

63. Various tasks and responsibilities of the regional agencies can be summarized in the following manner:

- Coordination between SWERA team and national partners of the region so that activities and schedules are maintained.
- Assistance to national partners in data quality assessment & refinement.
- Work closely with NREL & Risø in the development of maps and receive incremental capacity building in assessment techniques including modeling.
- Provide capacity building to national organizations in use of resource maps and SWERA tools for energy planning.
- Dissemination of SWERA products and outreach to investors.

Activity 5.2 Meetings

64. Regional meetings will be held during project startup and during the development of the final report on the project. National assessments, regional mapping efforts, and integration/ extrapolation of global significance of the assessment will be developed through this exercise and recommendations made for further improvements in assessment methodologies and coverage. Sharing of information through common training exercises, sharing experiences and validation approaches during the assessment activities will enhance the quality of the assessments

STAKEHOLDER PARTICIPATION AND IMPLEMENTATION ARRANGEMENTS

65. A global network of international and national agencies with various technical interests and support services in solar and wind energy resource information and assessment will be established. Stakeholders will be the European, American and other wind energy associations and the American, International and other Solar Energy Societies. Other International Agencies like the World Solar Program of UNESCO, UNDP/GEF will also be integrated. These stakeholders will assist with the development of the facilities and represent the solar and wind technology providers and some investors.

66. UNEP/DTIE, will be the executing agency for the project. The executing agency will manage the project and be accountable for the effective use of the resources. A Project Manager will be established within UNEP to implement the project on a full time basis. The Project Manager will supervise subprojects with national and international collaborating agencies. Consultation and negotiation with Governments and investors will be an important function. Project execution will be by UNEP in collaboration with NREL, Risø, TERI, INPE, DLR and national agencies in all pilot demonstration countries (list in Annex F Implementation Arrangements – Agency Roles).

67. Regional meetings were held in Nairobi, Delhi, and São Paulo. Participants included industry, assessment experts, energy officials from governments and non governmental organisations. Meeting reports are available on request. Further stakeholder participation will be encouraged through world wide web based information exchange during the project execution.

68. A Steering Committee will provide advice to the project manager on activities, monitor and guide the implementation of the work plan, review the budget and address significant implementation problems. The Steering Committee will consist of members from UNEP/DTIE, NREL, Risø, TERI, INPE, UNEP/ GRID, and DLR. The World Bank and UNDP will be invited to participate especially for the coordination of country activities.

69. The SWERA team consists of technical resource assessment and GIS experts from NREL, Risø, TERI, INPE, DLR, and UNEP. This team is responsible for actual execution of the mapping, database development, and GIS technical support activities. Their services will be provided on demand from the national agencies through UNEP/DTIE.

70. TERI and INPE will act as Regional Agencies during the pilot project based on their ability to sustain activity in these areas. Their services will be concentrated on their immediate regions but they may supply similar services elsewhere. In China, CRED will work directly with the SWERA team. In Africa the support services will be shared by UNEP and the SWERA team.

71. National Stakeholders will include electrical utilities, private sector solar and wind energy technology providers, investors, NGOs, Ministries of Energy and other relevant government departments.

RISKS AND SUSTAINABILITY

72. SWERA can only be successful if governments of participating countries show strong and continuous commitment to the project and renewable energy. The interest and support of the wind energy associations, the solar industry associations, investors and governments will also be needed. Based on interest expressed during project development, this is likely.

73. Replicability has been addressed through the selection of two regional agencies that will be able to carry on assessment services after SWERA Pilot Project. The global archive will be maintained by UNEP/GRID with their other databases.

74. This project, in and of itself, may not directly stimulate accelerated investments in renewable energy projects. Other barriers, such as policy or economic barriers, may also need to be overcome in certain countries before expanded investment occurs. However, in absence of reliable and precise resource data, solar and wind energy projects/programs will not take off, even if all other barriers are removed.

INCREMENTAL COSTS AND PROJECT FINANCING

75. Baseline meteorological measurement programs do not provide sufficient information for solar and wind energy assessment as they are designed for other purposes and measurements are only funded by GEF or when they lead to actual investment. Mapping of the potential resources and their integration into a GIS format provides incremental activity to the baseline in most countries. Information of the resource potential will trigger the follow-on investment activities. The baseline meteorological measurements are still needed for agricultural and transport purposes. Assessment and mapping model development has taken place in the technical supporting agencies that can be capitalised on by the GEF and will set up a sustainable activity area for further regional assessment projects.

76. Letters of cooperation has been exchanged with GTZ offering to support SWERA through the TERNA Wind Measurement Program. The monetary value is estimated based on similar past TERNA projects and cannot be determined until additional constraints of the TERNA program are satisfied within each country. The funding is shown against National Alternative Development Scenarios.

77. The SWERA project focuses on removal of information barriers through satellite and computer modeling techniques, and building the capacity in the national collaborating agencies to

use this information and contribute to the output of the project. Capacity building is therefore limited in scope and extensive follow on activities will be needed. Capacity will be increased incrementally from each country's baseline where they can become sustainable.

78. Use of the information is the most critical barrier. Proficiency in the use of the information and tools in activities 3 and 4 are therefore the most important. For advanced countries and especially for the regional agencies, access to the complete GIS data sets will permit more sophisticated GIS applications.

79. Knowledge of wind measurement is also crucial to the national capacity. Since only a core capacity will be established during the national activities, additional funding for pre-feasibility studies and expanded training will be necessary before investment. The firm understanding of the wind data by national collaborating agencies will be able to support further development of national policies and plans. Knowledge of solar measurements will also be beneficial.

80. Where countries/regional agencies already have measurement capacity and assessment capability the incremental effort will be redirected to allow them to increase their assessment capacity. INPE-Labsolar will perform a significant portion of the Latin American mapping activities. CBEE will work with NREL and Risø to refine their 30km resolution wind map in Brazil. TERI can perform wind measurements and assist with training and has used GIS tools effectively for assessment activities. During project initiation, the ability of agencies to perform additional assessment tasks will be investigated. The technical review activities in solar, wind and GIS will allow formulation of detailed responsibilities for assessment activities that meet the information barrier removal goals within the prescribed incremental budgets for the pilot project and build on the existing capacities in developing countries. One fifth of the total budget will be used through the national collaborating agencies and is expected to be matched by in-kind baseline activity. The activities executed by national agencies in each pilot country in support of the assessment and demonstration will require 50 to 100 k$. These activities will be targeted during project initiation and not conflict with associated projects.

INCREMENTAL COSTS

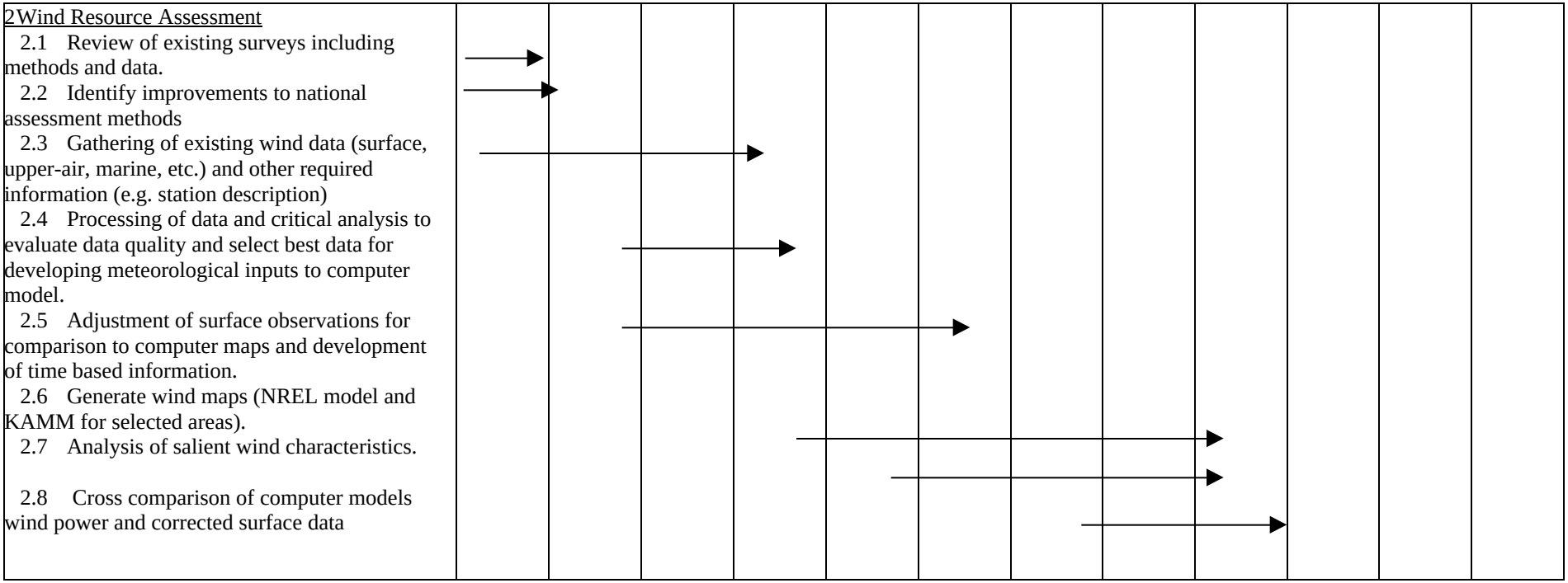
	Baseline	Alternate	Increment
Global Environmental Benefits	Lack of solar and wind energy resource data leads to continued dependence on fossil fuels. High emissions of GHG from conventional energy systems that use fossil fuels. Lack of integrated use	Solar and wind investment accelerated through solar and wind energy resource information dissemination and GIS tools and applications. GHG emissions reductions through improved project design and increased investments in solar and	Significant GHG emissions reductions through improved engineering and targeted investments in solar and wind energy projects. Incremental cost and energy savings due to proper

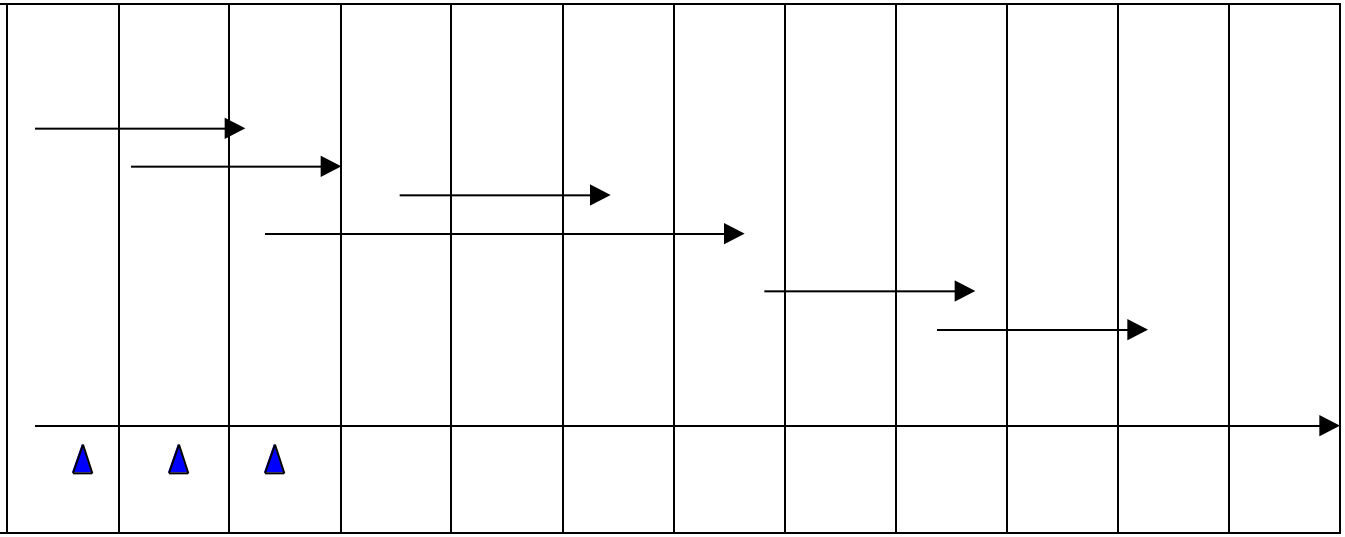
	of geo-spatial, solar and wind energy resource data in energy planning.	wind energy projects.	system sizing from more accurate and reliable solar and wind energy data.
Domestic Benefits	Least cost energy planning that continues to deploy conventional fossil fuel-based energy systems.	New investment in solar and wind supports rural development and grid supplies Solar and wind energy systems reduces local pollution and reliance on imported fuels Inclusion of solar and wind energy in the national energy system will diversify the energy supply.	Diversified energy supply, lower local pollution, and reduced energy imports resulting in economic savings in many cases. More robust energy plans and identification of opportunities for local and global environmental pollution.
Total Costs:	Total Baseline Costs: US$ $2,408,000	Total Project Costs:$9,020,000 GEF: $6,512,000 Cofinance:$2,508,000	Incremental Costs: $6,612,000 GEF: $6,512,000 GTZ: $100,000

	GEF	Cofinancing	Total
Activities			
1 Solar Assessment activities			
1.1 Method and Info review	35	23	58
1.2 Gather data	224	157	381
1.3 Develop Resource Maps			
South America region	385	156	541
Central America region	72	158	
African , Middle East	194	286	480
Asian subregion	470	173	643
1.4 Generate Time Series Data	148	100	248
1.5 Relate satellite and Ground series	101	25	126
1.6 Solar Comparison and Validation	213	90	303
Subtotals	1842	1168	3010
2 Wind Assessment		0	
2.1 Review Surveys and methods	29	115	144
2.2 Gather existing data	175	200	375

2.3 Preprocess data	35	100	135
2.4 Adjustment of surface measurements	87	0	87
2.5 Generate high res maps			
Latin Am & Caribbean	463	75	538
African subregion	428	0	428
Asian subregions	645	0	645
2.6 Prepare atlas info	115	0	115
2.7 Wind Comparison and validation	87	100	187
Subtotals	2331	654	2985
3 Integration with GIS			
3.1 Develop Standard Data sets	121	0	121
3.2 GIS Tool kit development	380	300	680
3.3 National GIS activities	169	39	208
3.4 Establish Global Archive	320	0	320
Subtotal	990	339	1329
4 National Applications of SWERA			
4.1 Alternate demand scenarios	260	217	477
4.2 Marketing	255	0	255
Subtotal	515	217	732
5 Networking and coordination			
5.1 Coordination	450	0	450
5.2 Coordination and meetings	384	130	514
Subtotal	834	130	964
Total	6512	2508	9020

Activities	2001				2002				2003			
1 Solar Resource Assessment												
1.1 Detailed review of existing solar radiation assessments (spatial an temporal resolution, validation studies, information product details)	→											
1.2 Adapt methodologies to regional conditions and define additional analysis required for consistency with SWERA products.		→										
1.3 Gather any additional solar radiation and other relevant meteorological data as needed.			→		→							
1.4 Generate model-derived spatially gridded solar data (eg. Collector orientation, or type)				→					→			
1.5 Generate time series data (Typical Meteorological Year, days of autonomy) using ground-based measured or modeled solar data.				→					→			
1.6 Cross comparison of computer estimated solar radiation and ground measurements sites							→		→			


2Wind Resource Assessment
2.1 Review of existing surveys including methods and data.
2.2 Identify improvements to national assessment methods
2.3 Gathering of existing wind data (surface, upper-air, marine, etc.) and other required information (e.g. station description)
2.4 Processing of data and critical analysis to evaluate data quality and select best data for developing meteorological inputs to computer model.
2.5 Adjustment of surface observations for comparison to computer maps and development of time based information.
2.6 Generate wind maps (NREL model and KAMM for selected areas).
2.7 Analysis of salient wind characteristics.
2.8 Cross comparison of computer models wind power and corrected surface data

Activities	
3 Geographical Information System (GIS) 3.1 Develop Standard Data sets 3.2 GIS Tool kit development 3.3 National/ regional GIS activities stablish Global Archive 4 National SWERA Application for development potentials 4.1 Alternative Development scenarios 4.2 Marketing and presentation 5 Coordination and Management 5.1 Coordination of project activities 5.2 Meetings	

Annex A Incremental Cost Matrix

Activity	Baseline	Alternative	Increment
1. Solar Resource Assessment	NASA low resolution global horizontal data set. Varying levels of information and quality in numerous studies primarily for meteorological and agricultural purpose.	High resolution (approx. 0.05° to 0.15°) and medium resolution (approx. 40 km x 40 km) solar resource (global, diffuse and direct radiation) maps and data sets will be developed for large regions of the world. Greater awareness of solar resource potential to meet energy requirements. Increased deployment of solar energy projects from use of more precise solar resource data.	Solar components and higher resolution information accelerates solar investment broadening applications at the margin of premium markets and supporting large-scale strategic investments in solar thermal electric, solar photovoltaic and other solar applications.

Activity	Baseline	Alternative	Increment
Costs	Total 1168k$ National Agencies, DLR, SUNY, NREL, INPE	Total 3010 k$	GEF 1842 k$
2. Wind Resource Assessment	Global map from the 1980s is composed of misleading measurement and interpolated data. Sparsely scattered, non-energy related ground measurements continue to be taken in many but not all countries. Some resource assessment capacity in medium-income developing countries.	High resolution wind resource maps (1 km x 1 km) for selected regions will be generated. More accurate knowledge of wind energy potential. Better information on good wind energy sites. Accelerated deployment of wind energy projects.	High resolution maps are incremental to national baseline activities in all countries considered. The increment will be additional to the current baseline so as to accelerate investment in wind energy development.
Costs	NREL and National Agencies 654 k$	Total 2985	GEF 2331
3. Integration with Geographical Information Systems (GIS)	Sophisticated GIS tools that are too cumbersome for the target audience. Energy planning without the benefit of easy to use geo-spatial information and accurate solar and wind energy resource data.	Broader awareness and confidence in solar and wind energy resources. Broadly accessible and usable solar and wind energy information.	Accelerated information dissemination and effective use.
Costs:	NREL and National Agencies 339k$	Total: 1329k$	GEF 990 k$
4. National Application of SWERA Tools	Low penetration of GIS in energy planning.	Use of simply GIS tools and high quality solar and wind energy resource data in energy planning.	Wider use of GIS planning tools and integration of solar and wind energy resource data in national energy

Activity	Baseline	Alternative	Increment
and Information	Lack of accurate solar and wind energy resource data.		planning.
Costs:	National Agencies: 117 k$	Total: 732 k$	Total: 515 k$ GEF: 366k$ GTZ: 100 k$ (est.)
5. Coordination	International networks exist but none comprehensively focused on solar and wind resource data.	Through links to other agencies and a global resource assessment centre, broader awareness and confidence in solar and wind energy resources is established leading to broadly accessible and easily usable solar and wind energy information.	An international network of regional centres and international technical institutions will provide technical support and information dissemination on the effective use of high-resolution solar and wind energy resource data. Startup costs and project coordination costs.
Costs:	International Collaborating Agency contributions to PDF and selected National Agencies participation costs: 130 k$	Total: 964 k$	GEF: 834 k$
Global Environment Benefits	Lack of solar and wind energy resource data leads to continued dependence on fossil fuels. High emissions of GHG from conventional energy systems that use fossil fuels. Lack of integrated use of geo-spatial, solar and wind energy	Solar and wind investment accelerated through solar and wind energy resource information dissemination and GIS tools and applications. GHG emissions reductions through improved project design and increased investments in solar and wind energy projects.	Significant GHG emissions reductions through improved engineering and targeted investments in solar and wind energy projects. Incremental cost and energy savings due to proper system sizing from more accurate and reliable solar and wind energy data.

Activity	Baseline	Alternative	Increment
	resource data in energy planning.		
Domestic Benefits	Least cost energy planning that continues to deploy conventional fossil fuel-based energy systems. Consumption of fossil energy produces high local pollution Importing of fossil fuels increases energy security risk	New investment in solar and wind supports rural development and grid supplies Solar and wind energy systems reduces local pollution and reliance on imported fuels Inclusion of solar and wind energy in the national energy system will diversify the energy supply.	Diversified energy supply, lower local pollution, and reduced energy imports resulting in economic savings in many cases. More robust energy plans and identification of opportunities for local and reduction of global environmental pollution.
Costs	Total Baseline Costs: US$ $2,408,000	Total Project Costs: $9,020,000 GEF: $6,512,000 Cofinance: $2,508,000	Incremental Costs: $6,612,000 GEF: $6,512,000 GTZ: $100,000

ANNEX B - LOGICAL FRAMEWORK/PROJECT PLANNING MATRIX

Project Strategy	**Objectively Verifiable Indicators**	**Means of Verification**	**Important Assumptions**
Operational Programme 6 Promotion of the adoption of renewable energy by removing barriers and reducing implementation costs. National development, energy diversification, reduced domestic pollution	(1) total capacity installed (2) technology costs (3) involvement and activities of national and/or multinational corporations (4) overall portfolios/activities of national and/or international private financiers, MDBs and bilateral aid agencies (5) national policies (6) awareness and understanding among national and international agencies and NGOs (7) energy consumption and fuel use patterns	*Market surveys* The market scope affected by this work will be large investors in wind and solar energy as well as smaller dispersed investors in rural energy Establish baselines for international market and measure trends over time. Solar energy societies and wind energy associations	*Replication.* Replication occurs across countries and from national markets to international market. *Relevance.* The most appropriate technologies, markets and countries have been included in the GEF portfolio. *GHG emissions.* Changes in market indicators correlate with reductions in greenhouse gas emissions over time.
Outcome Increased adoption and reduced cost of solar and wind energy development by providing higher spatial and temporal resolution resource information in a geographic information system planning tool enabling countries to remove information barriers and, as well, reduce implementation costs by prescreening locations of higher resource potential	Pre-investment measurement activities make use of the high-resolution maps and target the high potential areas. Availability of resource data stimulates policy reform that promotes use of solar and wind technologies for major development. Geo-spatial energy planning takes place. Solar and wind energy investment is accelerated.	The effect in pilot/demo countries is measured by counting follow-on investments, new measurement surveys, policy and planning and projects entering the pipeline.	Opportunity to displace fossil fuel use, good solar resource likely, good policy environment expected, especially in reducing use of high CO_2-emitting fuels, rising energy demand, interested investors.
Outputs			

Improved awareness of wind and solar resources Improved information quality and confidence New resources identified Reduced cost and time of pre-investment work Improved capacity for planning	Adoption and reference in bidding documents Increased estimates of potential Estimated time and cost savings Acceptance of the development projections and adoption of the method for further planning and policy work	Count CDROMs sold, web-site hits, people/agencies using maps and tools; incremental increase in the number of projects entering the pipeline over baseline projections Survey of wind/solar engineering firms doing preinvestment studies	Opportunity to displace fossil fuel use, good solar resource likely, good policy environment expected, rising energy demand, interested investors.

Activities	**Deliverables**	**Assumptions & Prerequisites**
1 Solar Assessment activities 1.1 Method and Info review 1.2 Gather data 1.3 Develop Resource Maps South America region Central America region African , Middle East Asian subregion 1.4 Generate Time Series Data 1.5 Relate satellite and Ground series 1.6 Solar Comparison and Validation	Technical reviews will be attached to the information in the database and available to support informed selection and use. In the case of existing or externally funded assessments, activity may end here. Data to be gathered and used Gridded solar radiation data combined with standard TMY data files Data sets and reports TMY data sets based on Ground measurement data, or data modeled from ground meteorological stations An estimate of the confidence limits for local conditions.	Availability of reliable ground data
2 Wind Assessment 2.1 Review Surveys and methods 2.2 Gather existing data 2.3 Preprocess data 2.4 Adjustment of surface measurements 2.5 Generate high res maps Latin America subregions African subregion Asian subregions 2.6 Prepare atlas info 2.7 Wind Comparison and validation	Technical reviews will be attached to the information in the database and available to support informed selection and use. In the case of existing maps externally funded, activity may end here. Status of existing information and plan for using it. List of data sets and information available for analysis. Results of data analysis and graphical output of selected data sets with inter-annual, monthly, and diurnal variations. High-resolution (1-km) annual average wind power maps and smaller area 5km wind maps with additional information. Report including summaries of salient wind characteristics (seasonal/monthly, diurnal, wind direction frequency, etc.) Summary of cross comparison in specific areas and modeling of channeled flow in some types of terrain	Availability of reliable ground data

Activities	***Deliverables***	**Assumptions & Prerequisites**
3 Geographical Information System (GIS) 3.1 Develop Standard Data sets 3.2 GIS Tool kit development 3.3 National/ regional GIS activities 3.4 Establish Global Archive 4 National Applications of SWERA 4.1 Alternative development scenarios 4.2 Marketing and presentation 5 Management and coordination 5.1 Coordination 5.2 Meetings	A user-friendly geo-spatial analysis tool developed for broad use. Existing GIS information on communities, roads, electricity grids, load centres, and other geo-spatial land use digital data is identified that can be incorporated A multi layer GIS data set in ESRI Arc/Info software format Development scenarios, GHG emissions impacts A demonstration of the ability of the GIS tools in the national context. Report on global status of assessment and energy potential Communication and information exchange facilities will be set up through UNEP, INPE, and TERI These will include use of internet and regional meetings Combined training, information transfer and feedback meetings will be held	Availability of country-specific geospatial data that is suitable for GIS tools Information is readily available without significant effort.

ANNEX C STAP ROSTER REVIEW

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September 4, 2000

Review and Evaluation of

Division for Technology, Industry and Economics (DTIE)
UNEP
GEF Solar and Wind Energy Resource Assessment (SWERA) Project

Project Summary and Evaluation Overview:

This is an ambitious project, designed to increase the knowledge base, and analytic and managerial capacity of both the international community and local governments to plan, implement, support, and evaluate the resources and cost effectiveness of the large-scale use of renewable energy systems. There are significant conceptual merits to this project, including: developing an international resource for renewable energy planning (and, critically, a standardized solar and wind data base); developing standardized assessment methods and project procedures; and expanding the range of trained national and international renewable energy experts.

The implementation of this plan as described in the current proposal, however, is less certain to benefit local and the international market for sustainable renewable energy technologies. In an ideal world, much of the plan and ideas presented in the project brief (SWERA PB8.doc & related documents) are promising and should be completed. Specifically, there is an obvious need and role for a global archive of wind and solar resources as well as system design software. This should be developed. The wider use of that information in developing local capacity (and international support) for renewable energy projects, however, requires additional planning, coordination, and – critically – international as well as local agreement and input.

The experience of the GEF and other national and international efforts in a number of areas needs to be strengthened. The use of software tools to facilitate local decision-making (as a historical example, the LEAP software) needs to be designed with an expanded round of inputs from prospective users, and recipients of the resulting planning decisions. A range of management options and resources for hardware and vendor/installer certification programs would benefit from expanded levels of local input to avoid some of the mistakes of the past (see, e.g. Foley, 1995; Maboyi, 1995; and Kammen, 1999). That does not mean that with continuing evolution and self-examination that they can not improve, but that the degree of critical review of past projects has not *as yet*, been sufficient to suggest that this project will be of maximum benefit the intended beneficiaries. A variety of study, testing, and local consulting and partnership components are needed first.

In the body of this review I will highlight and comment on these strengths and weaknesses, and illustrate the actions that could be taken to build the foundation of national and international renewable energy infrastructure so that this sort of project would significantly develop and support emerging clean energy industries. In summary, I recommend a process that will involve added, and more diverse, input from the emerging private sector that will implement many of the renewable energy industries, and greater voice and direct involvement of intended recipient groups. These features could be institutionalized to foster added channels and mechanism for local input and response can be developed. It is important not to move forward unless the need for expanded local capacity and input can be addressed. Documents such as the GEF report, the **Thematic Review of the GEF Solar PV Portfolio: Emerging Experience and Lessons,** ***by Eric Martinot, Ramesh Ramankutty and Frank Rittner, illustrate the need for this wider process of external input, review, and management of the mapping and policy planning process. In light of these concerns, the Annex on*** Incremental Capacity Building ***is insufficient.***

As one of many interested observers of the process of support and development of multinational renewable energy projects, I would be willing to draft a more complete plan for the sort of local-global dialog that is needed for greater responsiveness to meet specific development challenges with clean energy systems.

General Comments:

A particularly promising aspect of this project is both the range of nations and the number of program offices and organizations that will be consulted and involved in project planning. While this can become operationally challenging, it remains a key aspect of developing sustainable institutions to support renewable energy industries.

The comments in this review include, but are not limited to the specifics of the solar and wind energy resource assessment, evaluation, and analysis. This is a necessary analysis of the broader context for such a project. The motivation for this is stated in the project brief (Paragraph 3), which notes that the commitment of resources and planning activities surrounding energy resource assessment can influence policy and national planning.

A number of specific recommendations for action prior to implementation of the SWERA project include:

Further analysis and input regarding the benefits, and concerns, surrounding, international programs such as the Photovoltaic Market Transformation Initiative (PVMTI) as a means to build local market capacity. While the basic mechanism of market transformation remains a critical tool in the development of local clean energy markets (Duke and Kammen, 1999), unanswered concerns regarding both local implementation and the involvement of local businesses do exist. An analysis of the best ways to support local market development would be an appropriate first step. This should include both a commissioned report and an open series of discussions that involve diverse groups (public and private sector, and aspects of civil society, such as Non-Governmental Organizations and local village cooperatives) interested in renewable energy markets and technologies.

Evaluation of the mix of grid, stand-alone, and non-electric resources that would most benefit local development should be undertaken. Software tools, such as HOMER, can be invaluable in assessing local energy resources and the cost-effectiveness of various energy systems. At the same time, many such tools place a particularly strong emphasis on single-mode (electrification) planning. There are wide range of energy applications – such as mechanical water pumping, solar thermal applications – that can cost-effectively serve local needs. Models such as HOMER need to include these options for energy and financial resource allocation to best serve local needs.

The project brief calls for efforts to build investor interest in renewable energy industries, which is critical for long-term market development. This needs to be supported by sufficient levels of local training and review of both the technical and social/managerial systems to benefit end users. One means to accomplish this is to develop independent review and advising networks and organizations that can comment on the SWERA projects, and on the changes that will likely take place in local energy markets. One example of this has been the review of the evolution of the Kenyan photovoltaic market. In that work an interdisciplinary group looked at both equipment issues (in particular the use of amorphous versus crystalline photovoltaic panels, as well as battery performance) and the interaction of vendors and end users (Duke and Kammen, 2000; Duke, *et al*, 2000; Jacobson, *et al*, 2000a,b).

Too much of the technical analysis, mapping, and resource evaluation to take place in this project appears to be scheduled for completion by the international partners, notably NREL and Risø. While the expertise of both organizations is important in model development and use, a far higher percentage of project resources (both human and financial) could and should be devoted to developing and training, and transferring, these capacities to local groups beyond the government partners identified for each national team. These organizations – both governmental and non-governmental, could then take a lead role in performing the analysis.

The budget, incremental cost annex, and budget particulars are satisfactory given the contents of Project Draft 8. As outlined in this review, however, a great deal of further refinement of this projects is recommended, which will greatly alter this budget.

Specific Comments:

Page 1:
Developing these resource assessment and implementation capacities in Cuba is an excellent goal, and should be supported.

Paragraph 4:
There is no question that the development of reliable and freely accessible renewable energy resource maps are a key resource for project planning and evaluation. Construction of this data-base can address both local development issues, national energy concerns, and global environmental concerns. This aspect of the project should take place. At the same time, it is important to evaluate and incorporate a greater range of local perspectives and inputs on what sort of systems would prove useful to meet local energy and development concerns.

Paragraph 6 – 12 and ff:
While it is true that very few pyranometer and other official solar and wind resource stations exist in developing nations, a growing number of non-governmental organizations are able to perform these measurements and make use of the results (Kammen, 1999). A useful step would be to support the growth of such a resource monitoring *and evaluation* network. There are obvious benefits to doing this in terms of supporting local capacity development. The GIS capacity is also one that can be diversified, which will benefit both the growth of the global data base, and the involvement of local organizations. The network of agencies discussed at the end of Paragraph 12 for this networking, for example, is excessively focused on official institutions.

Paragraph 13:
The proposed Steering Committee, is excessively focused on official organizations that often agree in advance on priority that various tasks should receive. This body needs to be diversified.

The call for the Regional Agency (Paragraph 15) to support local capacity building needs to both reflect the wider set of stakeholders (as discussed above), and to explicitly support capacity building in groups that extend *beyond* federal and state organizations. There is a consistent theme, and worry, that the processes involved in building this resource mapping capacity will remain focused on the set of goals enumerated by the international team (e.g. NREL and Risø), and their partner organizations and individuals within the local governments. A crucial example of the interplay between resource mapping activities, and renewable energy planning appears in Paragraph 17 (**ACTIVITY COMPONENT 2: SOLAR RESOURCE ASSESSMENT)**. Little distinction appears between resource mapping and project planning activities. While many of the individuals involved in one phase will be involved in the other, critical questions of development priorities, local needs versus state and international interests, should at this point benefit from a far wider form of public, private, and state involvement, interaction, and evaluation.

Paragraph 17:
After Paragraph 17 the numbering system jumps from 17 to 31, and then paragraphs are interspersed out of clear order thereafter.

Paragraph 52:
Access to the solar and wind resources is ambiguous. The project results, as they are developed, should be placed on open access www sites. This data should not be limited in release for either

government offices, or for participating nations alone. Large-scale growth in clean energy markets can be supported by making this material easily and freely available. As written in the project draft, the control of access to this information is both highly limited and highly troubling.

Paragraph 58 ff (Activity 4.2):
Again, the need for greater local involvement, *and control* over the development of technical tools is apparent. This process needs to be one designed to both transfer expertise, and to support local technical and managerial capacity and control. At present, the document suggests too great a degree of project design, and implementation by the international organizations that while well skilled to develop the software and other project components, can not themselves build sustainable local energy industries. Greater, earlier, input and buy-in by not only governmental organizations but also the private sector and civil society in the recipient nations is needed.

Paragraph 67-68:
Design, planning, and implementation of the case studies should be determined and implemented by local organizations.

Paragraphs 72 – 75:
The level of local control over the project is left unclear. Certainly governmental involvement from at least some of the host countries is specified (e.g. China). A wider process of meaningful participation and control is needed. No indication exists that the problems of the Zimbabwe GEF project, or the PVMTI process, will not be present in the current project.

Paragraph 78
'of' is repeated in line 1.

Paragraph 80:
The Annex on Incremental Capacity Building ***is insufficient.***

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ANNEX C1 RESPONSE TO STAP ROSTER REVIEW

The reviewer correctly identifies the broader capacity building and stakeholder consultations that are needed to achieve wider spread adoption of energy planning tools.

This project proposes to develop resource information that will be needed and as well build and exercise the core tools for energy analysis. Output to a standardised data format will allow the expansion of tool development that will ultimately see the achievement of broadly utilised science based decision making. The specific project outputs do not promise broad applicability.

The project will provide a simple spreadsheet output facility that can be adapted or converted to appropriate inputs to common software such as RETScreen.

Response to Specific Comments

Paragraph 4:

Local stakeholder meetings will be included in the nationally executed activities to achieve local consensus on development needs.

Paragraph 6-12 and ff

Local non-governmental institutions will be included in the local networks especially where they have data and skills to offer.

Steering Committee:
The steering committee is intended to function by conference calls and through electronic media. The committee will include of additional country representatives.

Para 15

According to upstream guidance from the GEF the project will seek associated projects and opportunities through the UNEP/DTIE technology transfer clearing house to accomplish broader capacity building and stakeholder involvement.

Para 52

See terms of reference for UNEP/GRID all solar and wind energy information will be available on the SWERA website.

Para 58 ff

Increased effort has been directed to the development of National Energy development Alternatives (activity 4)
Para 67,68, 72-75

National agencies and stakeholder groups will identify the resource information needs and will execute the most important work under activity 4.

Para 80

Additional capacity building will be targeted at investors and developers through the Technology Transfer Network project (commencing 2001) and through linkages to the UNDP China, Sri Lanka, Brazil; World Bank Nicaragua, China and GTZ global programs. Further capacity building needs can be assessed during the project execution.

Annex D: Incremental Cost and Global Environmental Benefits of Improved Solar and Wind Energy Resource Information

Slowing and eventually reversing the growth in global greenhouse gas emissions will require, among other initiatives, the large-scale use of renewable energy technologies for production of thermal energy, electricity, and fuels. The Global Environment Facility is committed to supporting the use of renewable energy technologies on an unprecedented scale throughout the world. The lack of reliable and sufficiently detailed and easily used solar and wind energy resource data is a *primary obstacle to both public-sector and private-sector investments in renewable energy applications in the developing world.* Thus there is a significant need to develop refined estimates of these resources world-wide, and to incorporate the information into a Geographic Information Systems (GIS) framework that will support effective regional and national planning, and prudent renewable energy investment decisions

The purpose of the Global Solar and Wind Energy Resource Assessment (SWERA) project is to provide reliable high resolution and consistent solar and wind energy resource data and information to help non-Annex I countries identify and develop their solar and wind energy resources for power generation and thermal energy production. By providing data in Geographic Information System (GIS) format, the project will facilitate national planning efforts to mobilize these resources. This is an *information* development and dissemination project, and does not provide funding for renewable energy project identification or development. The specific SWERA project goal is to remove the barrier that insufficient wind and solar resource data present to broader and accelerated development of solar and wind energy facilities.

The purpose of this annex is to compare the incremental costs of the SWERA project with the associated projected global benefits. The calculations presented here assume that the investment in providing better solar and wind energy resource data to a country will initiate or accelerate the development solar and/or wind facilities. We assume a 20-year operating life for both solar and wind installations.

Intuitively it would seem reasonable to assume that the cost of avoided carbon emissions associated with the use of *information* to accelerate and expand the use of solar and wind energy technologies is going to be very low. This is borne out by the simple analysis presented here. Information is cheap compared with the cost of building, installing, and operating equipment. For a conservative wind electric power development scenario (below), the calculated *incremental*

cost of avoided carbon is about $ 0.02 per ton, almost three orders of magnitude less than the figure of $ 10.00 per ton typically cited for carbon trading values. This is for a wind farm operating at a conservative capacity factor of 30 percent, and displacing natural gas.

The Benefits of High Quality Solar and Wind Resource Information

Some of the near term impacts and benefits of developing and disseminating high quality solar and wind resource information are the following:

- National energy plans will be revised to take into account the realistic potential for solar and wind energy projects. In some countries, large-area high-resolution wind and solar resource mapping is expected to reveal far larger commercial wind and solar project development potential than currently thought possible. For many (perhaps most) countries the renewable energy targets will be raised dramatically, reflecting the new resource awareness and knowledge.
- New national and regional policy initiatives will be designed to remove barriers and attract investment for solar and wind project development.
- National and international investors will expand their solar and wind project activities in non Annex I countries.
- Bilateral and multilateral agencies (e.g., GEF, multilateral development banks, UNDP, UNEP, etc.) will expand their support for solar and wind projects in non Annex I countries.

From a global environmental perspective, the long-term impact will be a decrease in the rate of growth in greenhouse gas (GHG) emissions, through earlier and larger scale deployment of renewable energy systems than would have occurred in the absence of high quality resource data.

Examples of the Impacts of Improved Solar and Wind Resource Information

There is growing evidence that the national availability of high quality validated solar and wind energy resource data and information can facilitate a significantly greater effort to apply renewables in that country.

> *Philippines Wind Energy:* In the Philippines, a recently completed national wind resource atlas[3] has demonstrated that the potential for commercially viable wind electric power generation is tens of thousands of megawatts, not a few hundred MWe as was previously thought. This in turn has stimulated significant interest and project exploration activities by both the public and private sectors. The prefeasibility study for a 40 MWe wind farm (the first important wind installation in the country) was initiated by the Philippine National Oil Corporation (PNOC) within six months of the completion of the wind atlas.
>
> *Dominican Republic Wind Energy:* A recently completed high-resolution wind mapping and a comprehensive wind atlas of the Dominican Republic has greatly accelerated interests in wind energy applications by removing lack of wind resource information as a significant barrier. At a presentation of the wind atlas results in May 1999, the President of the Dominican Republic Senate stated the atlas findings remove a long-held misconception that the wind resources in the country are insufficient for significant

[3] "Wind Energy Resource Atlas of the Philippines", NREL (March 1999)

development of wind technology. The Senate President noted these findings should help convince the Senate Energy Committee to propose and pass new legislation to facilitate wind energy development.

Mexico Wind Energy: High-resolution wind maps and other assessment information were developed in the late 1990s for two regions of Mexico – the Yucatan peninsula and Baja California Sur. Two Mexican institutions are using this information and strongly support this type of wind mapping for additional regions of Mexico. The institutions are CFE (the federal electricity commission) and FIRCO (the federal agency for water and agricultural development). The wind resource assessment revealed commercially exploitable wind resource where previously it was thought that there were no important wind resources.

China Wind Energy: For China, high-resolution wind maps and other assessment information were developed for coastal regions of Fujian and eastern Guangdong provinces and inland region around Poyang Lake in Jiangxi, Anhui, and Hubei provinces. The State Power Corporation of China (SPCC) strongly supports wind mapping for additional regions of China, with special interest in large-scale off-shore wind farm development to service urban centers (and displace coal in power generation). Senior Chinese officials have recently said that this additional high-resolution wind mapping is key to attracting significant foreign and domestic investment in massive wind farm development in coastal regions.

India Solar Energy: In support of the development of several potential concentrating solar power projects in India, high resolution solar mapping techniques were used to produce direct normal solar resource maps for all of India and surrounding regions. These maps have had significant value toward the development of a GEF-supported solar thermal feasibility study in northwestern India. These same maps have been used to support the evaluation of resource potential for village-scale concentrating solar power collectors in the Tibet Autonomous Region.

South Africa Solar Energy: Using a world-wide surface meteorological database a solar atlas for South Africa is being developed. This atlas will contain long term hourly solar resource data for more than 60 locations throughout South Africa and surrounding regions. Eventually a high resolution solar resource map will also be prepared for the region, allowing access to the spatial and temporal solar resource information for the region. Part of this work is to support the widespread deployment of solar home systems in South Africa; other aspects of the work support South Africa's electric power utility ESKOM, in its evaluation of potential sites for concentrating solar power stations.

This is also true in Europe, Japan, and the United States. Extensive wind resource assessment has been conducted for the OECD countries that lead the world in wind energy and solar energy applications. These include (for wind) the USA, Germany, Spain, Denmark, Holland, Italy, and the UK. For solar energy applications, the ready availability of tools to generate high resolution solar energy data on an hourly basis has made it possible to calculate the *value* of photovoltaic generated power in urban environments, including building integrated PV systems. Due to the coincidence of PV generated electricity and peak power demand (driven by air conditioning), detailed analysis made possible by the high time and space resolution tools has revealed dramatic potential. PV systems in many parts of the US can displace 50% or more of grid generating

capacity, as well as most of peak load electricity production, and can do so at a cost that is or is close to being fully competitive.

Because the urban environment through most of the non Annex I countries is very similar to that of the OECD countries, with even greater potential midday air conditioning loads, access to these insolation data can open host country markets to very large long term use of photovoltaic systems. In Japan, where large scale use of PV systems is beginning for building integrated applications, such data are essential for calculating both technical performance and economic characteristics of these installations. In fact, a recent paper by the Brazilian Solar Energy Laboratory LABSOLAR , on the uncertainty analysis of the impact of solar radiation data quality in solar energy technologies (water heating and grid-connected PV) clearly demonstrates the importance of detailed and precise resource assessment. Strategically siting of building-integrated PV systems is also a topic under study in Brazil

A Case Example for Preliminary Calculations

The U.S. National Renewable Energy laboratory (NREL), in collaboration with the Government of the Philippines, has conducted a wind energy resource assessment for the Philippines, and produced a high-resolution (1 km by 1 km) wind map for the entire country. The cost of that effort, which included preparation of the detailed documentation, cost ca. $250,000, including both Philippine and USAID financing. Prior to the NREL analysis the official projection for wind electric power in the Philippines over the coming decade was ca. 100 MWe. In the very conservative scenario shown below, 480 MWe of wind capacity are in place by 2008, with perhaps 2,000 MWe installed by 2015. The scenario assumes that the Philippines government puts in place the policy initiatives that will attract private sector investment in wind power plant development.

A Possible Scenario for Wind Power Development in the Philippines

A "medium" scenario is presented for the possible development of commercial wind electric power plants (“wind farms”) over the period 2000 through 2008. It is assumed that early in this period the national Government (Philippines Department of Energy and others such as the Philippine National Oil Corporation or PNOC) will have initiated site identification activities. These would include detailed wind energy measurements with anemometers, to facilitate both private and possibly public sector investments in wind farm developments. The annual increments in installed wind electric power generation (rated busbar power) are shown in Figure 1 and the associated cumulative installed capacity in Figure 2. Table 1 describes how the commercial application of modern wind turbine technology might reasonably proceed in the Philippines, assuming that this is technically, economically, and financially justified, and that the necessary policies and practices (e.g., power purchase contracts) are in place.

In this conservative scenario 480 MWe of wind farm generation capacity are in place by the end of year 2008, representing roughly a half billion dollars of investment. Assuming a 25% capacity factor on average, the annual electricity production would be 1,050 GWh, less than 2% of projected Luzon electricity demand in the year 2008. In the ten-year period from 1996

through 2005, installed wind generation capacity in Denmark was projected by the European Wind Energy Association to increase by 1,300 MWe, from 839 MWe to 2,135 MWe. During that same period Spain is expected to add 2,200 MWe of wind electric capacity to the 1996 capacity of 249 MWe. In that perspective, installation of 480 MWe of wind electric capacity in 8+ years in the Philippines is a plausible scenario, one that senior Philippine and World Bank officials are increasingly viewing[4] as *too conservative!*

To illustrate the plausibility of the assumptions, the annual wind electric capacity additions for the period 1989 through 1998 are shown in Figure 3 and Table 2 for China, India, and several European countries. The scenario for wind electric capacity addition in the Philippines is also shown for a ten-year period one decade later (from 1999 through 2008). The wind electric capacity that will be installed in the Philippines will be through international joint ventures involving companies that have developed wind farms in Europe, the U.S., and Asia. It is reasonable to assume that the deployment rates (MWe/year) in the Philippines could be comparable to those in other countries.

In the subsequent ten to fifteen years after year 2008 it seems reasonable to assume the further addition of two to three GWe of wind electric power in the Philippines, if there are technical and economic justifications for this. The wind resources are certainly sufficient to permit this scale of deployment. The challenge for the Government, industry and financial community is the establishment of the right incentives and policy environment that could attract the required investments in wind electric power development. In part as a result of the new wind resource data and perspective, the Philippines Department of Energy is altering the policy environment to facilitate dramatically increased use of renewables in the Philippines energy mix, both for grid connected and off grid applications.

The Cost of Reducing GHG Emissions through Improved Resource Information

Table 3 summarizes the calculation of the cost of reduced GHG emissions in terms of US$ per ton of avoided carbon. The calculation assumes that 400 MWe of wind generation capacity (at 30% capacity factor, displacing natural gas power generation) is installed over the coming decade as a result of the new (1999) high resolution wind maps and data for the Philippines. There would have been some development of wind power over this period (estimated at 100 MWe) without the new resource data. The cost of the wind mapping and wind atlas production was about $250,000. The cost per ton of carbon avoided over the twenty year life of the wind power plants is about $0.02. This is one five hundredth of the figure of $10 per ton of carbon often used as a ceiling for GEF leveraged investments.

For any country participating in the SWERA project that adds a few hundred megawatts of wind power systems over the coming decade as a direct result of having high quality wind data the figures will be roughly the same. Even if a small country adds only ten megawatts as a result of the SWERA project (assuming a mapping cost of $100,000 to $200,000), the cost of avoided carbon will be less than $0.50 per mton (metric ton). The arguments are exactly the same for

[4] E. Terrado (World Bank) and R. Bomasang (Chairman, PNOC Exploration Corporation); *private communications,* 2000

solar installations, with an average capacity factor in the range of 0.15 to 0.25. Hence the calculations are carried out using just the wind example. Note that the cost of renewable energy based power generation relative to the cost of the baseline generation (e.g., coal, oil, or gas) is not discussed and is not relevant to these calculations.

Wind and Solar Scenarios for non Annex I Countries

The non Annex I countries with the greatest global environmental impact of renewable energy systems use are China and India, with ca. 40% of the world's population, rapidly growing per capita energy demand, and huge fossil fuel reserves dominated by coal. Other strategically important countries include (for example) Brazil, Mexico, the Philippines, Indonesia, South Africa, and Egypt.

Table 1
An Illustrative Scenario for Wind Power Plant Development in the Philippines (1999 – 2020) with ca. $120 million in Near-term Investments (through 2005)

Year	Activity	New Wind Capacity (GWe)	Total Wind Capacity (GWe)
1999	Completion of Wind Resource Atlas of the Philippines, preliminary identification of potential sites for wind farms	0	0
2000	Site identification, characterization, and ranking for development. Initiation of detailed anemometer measurements. Preparation for pilot 10 MWe commercial plant (public/private venture?)	0	0
2001	Ongoing wind resource measurement at the best sites; commissioning of the first 10 MWe plant; development of two 20 MWe wind farms	10	10
2002	First 20 MWe wind farm built and commissioned	20	30
2003	Second 20 MWe plant commissioned; additional wind power projects under development	20	50
2004	Commercial wind plants come on line	30	80
2005	Major international investment and development of wind farms, 40 MWe plants come on line	80	160
2006	Continuing and expanding commercial investments	80	240
2007	Continuing and expanding commercial investments	120	360
2008	Continuing and expanding commercial investments	120	480
2009-2015	***Expanded investment activities***	***>2,000***	***>2,500***

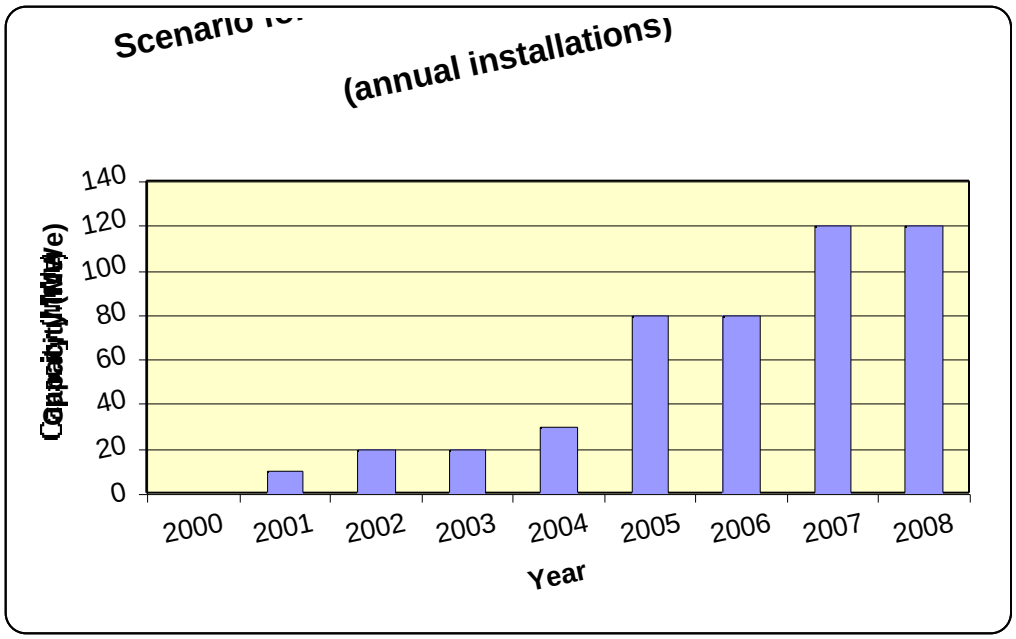

Figure 1

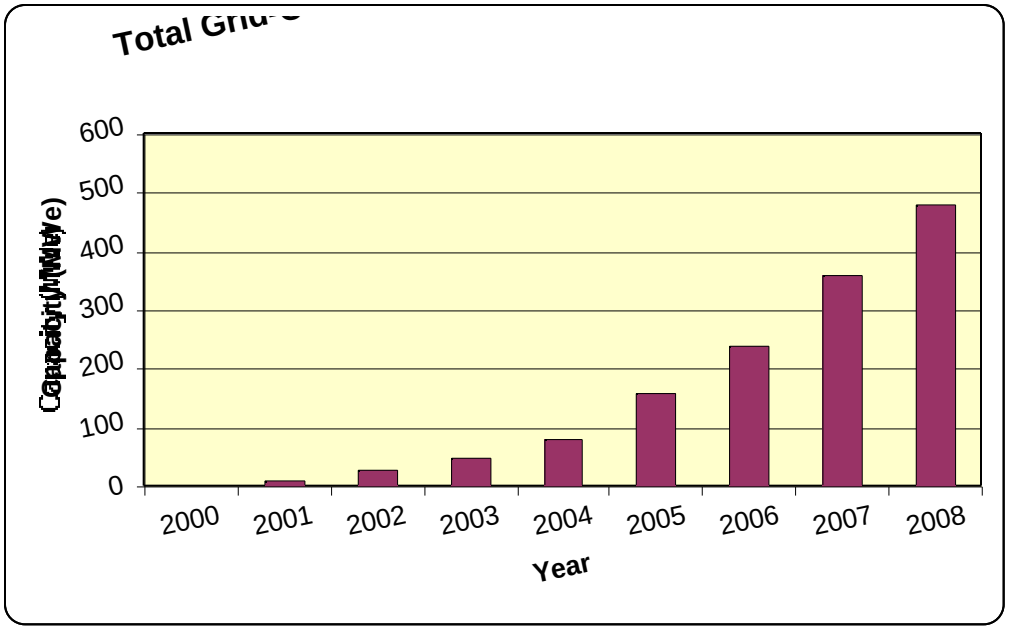

Figure 2

Table 2: Comparison of Historical Wind Electric Power Installations in Asia and Europe with the Scenario Projections for the Philippines

Year	Germany	Denmark	Netherlands	Spain	China	India	*Philippines*	*Year*
1988	10	81		0		12	***0***	***1998***
1989	14	65		0		20	***0***	***1999***
1990	40	80	15	8		3	***0***	***2000***
1991	50	70	42	2		0	***10***	***2001***
1992	65	45	23	7	3	5	***20***	***2002***
1993	150	29	26	30	6	22	***20***	***2003***
1994	307	54	22	23	18	141	***30***	***2004***
1995	500	98	95	58	14	375	***80***	***2005***
1996	420	200	50	116	35	244	***80***	***2006***
1997	533	285	44	200	100	50	***120***	***2007***
1998	797	264	34	395	24	18	***120***	***2008***
Total	**2,886**	**1,271**	**351**	**839**	**200**	**890**	***480***	***Total***

Figure 3: Comparison of Historical Wind Electric Power Installations in Asia and Europe with the Scenario Projections for the Philippines

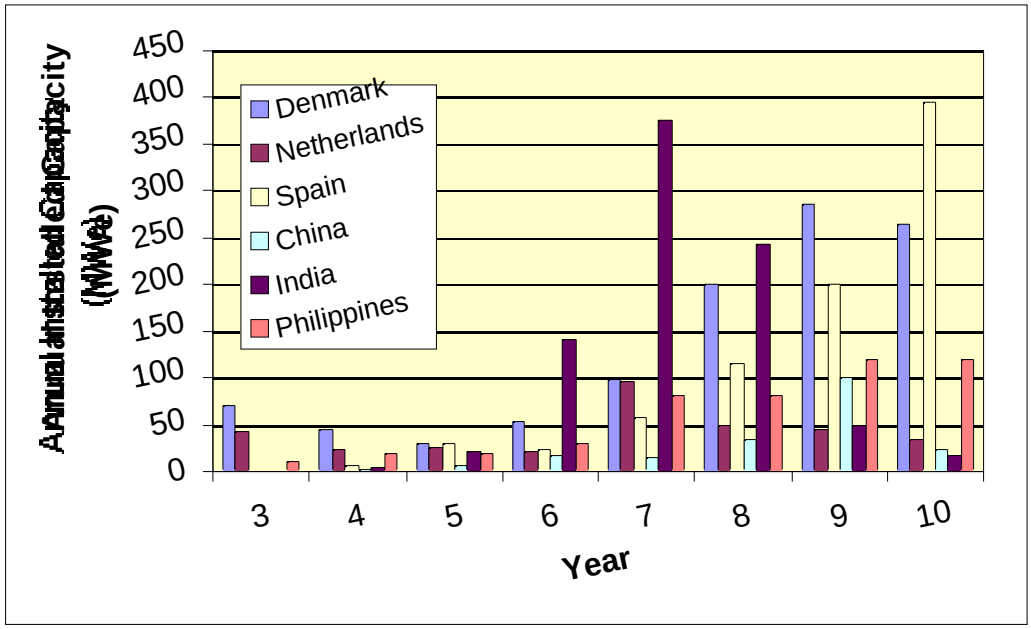

Table 3
Calculation of the Cost of Avoided Carbon Emissions due to Expanded use of Wind Power in the Philippines Relative to the Base Case

CO2/C	3.666667	Ratio of carbon dioxide to carbon by weight
C/CO2	0.272727	Ratio of carbon to carbon dioxide by weight

kgC/kWh	Emissions coefficients for indicated fuels
1.31	coal
0.96	oil
0.63	gas

		coal	oil	gas
kWh/year	CF	kgC/year		
1,752	0.2			1,104
2,628	0.3			1,656
3,504	0.4			2,208
4,380	0.5			2,759

Assume ca. 500 MWe instead of 100 MWe in ten years
400 MWe additional in place due to NREL wind maps
20 years of savings
natural gas power assumed to be displaced,
Wind plant capacity factor CF = 0.3, 20 years operation

13,248,000	mt of carbon over two decades
$ 250,000.00	cost of wind resource assessment
$ 0.019	Cost per ton for abatement

Information leveraging investment in wind electric power
Natural gas displacement with 30% CF is assumed

Baseline and Incremental Scenarios for Solar and Wind System Development

The baseline scenario for wind and solar development in a country assumes that the participating countries would not have access to data of the extent and quality that the SWERA project will provide. Developing *credible incremental scenarios* for wind power and solar power development in the SWERA participating countries is especially challenging. The example for the Philippines was possible because of the availability of a detailed wind resource assessment for the country. Without the data, the potential scale of applications cannot be estimated. Moreover, renewable energy initiatives such as electricity feed laws, renewable energy portfolio standards, green pricing, etc. can drive the demand for renewable energy facilities, in turn driving the demand for detailed resource assessments. Such initiatives have been used effectively in several OECD countries, but are not yet in wide use in non Annex I countries.

Table 4 GHG Related Parameters for SWERA Countries

Country	Parameter				
	Population (million)	GWe installed	Million mt carbon/year	Offset in 2020*	Offset in 2050*
Bangladesh	124	3.3	6.4	0.3	1.5
China	1,255	254.0	740.0	37.0	185.0
Ghana	19	1.2	1.1	0.05	0.3
Nepal	23	0.3	0.1	0.005	0.03
Nicaragua	5	0.5	0.8	0.04	0.2
Sri Lanka	19	1.6	1.4	0.07	0.4
Brazil	161	62.0	85.0	4.3	21.3
Guatemala	12	1.0	1.9	0.1	0.5
Cuba	11	4.3	8.0	0.4	2.0
Honduras	6	0.6	1.1	0.1	0.3
El Salvador	6	1.0	1.3	0.1	0.3
Kenya	34	0.8	2.1	0.1	0.5
Ethiopia	60	0.5	0.5	0.025	0.12
Total	1,735	331.1	849.7	42.59	212.45

Source: US Energy Information Administration (August, 2000 posted data for year 1998)

* 5% in 2020 and 25% in 2050 = Million mt of current carbon emissions that would be displaced by combined solar and wind installations in the years 2020 and 2050. The project estimated budget of US$ 6 million is leveraging almost 60 million tons of carbon per year for ten to twenty years (year 2020 scenario), at ca. US$ 0.01 per ton.

COMPARISON OF ALTERNATIVE METHODS OF WIND RESOURCE ASSESSMENT

Large-area wind maps have been developed over the past few decades using extensive wind measurement-based programs. In these programs, large areas have anemometers placed on a grid of 50 km or so, and computer models are used to "fill in" or interpolate between the measurement stations to create a map or profile of the wind resources in the area. More recently,

in the past decade, NREL has developed a wind mapping and resource assessment method Wind Resource Assessment and Mapping System (WRAMS) that uses sophisticated computer models coupled with extensive geophysical data sets to establish the wind resource with a resolution of 1 km by 1 km. This method has been validated in detailed studies in the U.S., and identifies regions of likely commercially interesting wind resources with a reliability of +/- 20% in wind power (+/- 10% in wind speed) for more than 80% of the area assessed quantitatively. This method permits the identification of regions that are potentially suitable for wind electric power plants. Once potential sites are identified based on multiple criteria (see below), detailed on-site wind measurements are made with multiple anemometers and at several heights (typically between 20m and 60m) to determine the actual potential for wind electric power generation.

In order to identify the relative merits of the techniques for large-area high-resolution wind resource assessment for the SWERA project an overview of the costs and benefits of modeling-based assessment vs. large-area measurement-based assessments is elaborated.

Advantages of Modeling over Large-Area Measurement Programs

There are enormous cost savings (about an order of magnitude) achieved by mapping the wind resource first and then targeting the wind measurements versus an extensive gridded measurement network plus some analysis method. Consider as an example a region of 2 million km^2 with measurements every 50 km. This would require about 800 measurement towers. The cost of a 2-3 year measurement program plus analysis would be about $25-$30 million. In contrast, mapping the wind resource using SWERA techniques and then establishing targeted wind measurement locations (say 80 towers for 2 years) would cost between $2.5-3 million. Since the wind mapping cost is ca. $300K, most of this cost is still due to the measurements. *The costs of wind energy resource mapping using modeling techniques are insignificant compared to the costs of an extensive wind measurement network.*

The quality of the final product is likely to be substantially greater in the lower cost option (wind mapping plus targeted measurements) than in the higher cost option (extensive measurement network plus analysis). The relative quality of resource assessment depends on several factors such as the wind resource variability, the topography, and how the measurement stations are located. Consider an example where only a small fraction of the land area is windy (such as the Philippines). If the measurement stations are uniformly placed without consideration of the topography or resource variability, then almost all the measurement stations may be located in the low wind resource areas. In the Philippines only 3% of the total land area has good-to-excellent wind potential. Since few or none of the uniformly-spaced measurement stations would happen to be located on windy ridge crests or exposed coastal areas, then the interpolated estimates of the measurement data from the low wind resource areas would not identify the many windy areas that exist. However, if high-resolution wind maps are first produced to identify areas likely to have good wind resource potential, then measurements could be targeted to the good areas to validate and confirm the wind resource estimates by the wind mapping.

Another significant advantage of the model-based approach, followed by targeted ground measurements, is that the areas of likely high wind resources can be identified within a few months, rather than in a few years. With the wind maps and the GIS format for the wind resource data, other data in GIS format can be combined with the wind maps to produce overlays

that will indicate the priority areas for commercial wind power plant siting. The other data include the locations of load centers, transmission lines and transmission corridors, power plants, and all-weather roads (for transporting wind turbines and heavy equipment such as cranes to the wind plant sites). Other features such as land slope, protected areas (wildlife preserves, parks, etc.), lakes and rivers, agricultural land, etc. can also be incorporated in a GIS-based wind power development assessment. Then, anemometers would be placed just within those sites that met the primary criteria for wind power plant siting.

India Case Example

In India, one wind monitoring station would be associated with about 500 km^2 of surrounding area. The costs of wind measurement equipment is readily available from web sites of vendors that sell this equipment. NRG Systems is a leading company that supplies wind measurement equipment worldwide for wind resource monitoring. They advertise a complete 40-m tower system for about $6,500. In India, in addition to equipment costs, there are costs related to manpower and travel (one trip to the wind mast per month, for three years). Then there are also manpower costs for data analysis. TERI[5] estimates the latter costs as follows:

2 persons x 10 days/month x 36 months = 720 person days
= 24 person months (PM)
= $ 16,000 ($ 700/PM assumed labor cost)

Travel = $ 4,000 (for 36 trips)

The total non-equipment costs per wind mast = $ 20,000. The total cost would be $26,500 per anemometer mast and associated data collection and analysis program for three years.

To cover ten percent of India's land area, or 317,000 km^2, it would require about 60 such measurement stations. By contrast, the modeling approach would yield high-resolution wind maps over this same area for a cost of about $100,000. (This assumes a $70,000 setup cost and $100,000 per million square kilometers). At the identified potential wind power plant sites, skilled meteorologists experienced in location optimal locations within windy areas would specify the location of the anemometers. These anemometers would be used to characterize the local wind resources in great detail, and the measurements would be used in conjunction with WAsP to determine optimal windplant layouts and the likely range of energy output as a function of time. This multistep process is far more efficient in time, money, and labor than using a blanket measurement approach to determine the overall wind resources in a country.

The on-site measurements and associated modeling and windplant layout and performance simulations would be the responsibility of wind resource development organizations, whether public, parastatal, or private. The SWERA project will provide the initial information that will permit a country or agency or industry to determine whether or not it makes sense to proceed with wind farm development in the country or mapped region.

General Case Example

[5] Communication from Amit Kumar, TERI

Assume that the cost of the wind measurement equipment represents most of the total cost for a wind measurement program. Under this scenario, labor costs, transportation and installation costs, customs duties, etc, are quite low and represent only a small fraction of the total costs over the duration of a 1-2 year wind measurement program. Under this scenario, the total costs could be as low as $10,000 per measurement site. For an extensive measurement program of 800 measurement sites over a 2 million km^2 region (one site every 50 km), this comes to $8 million. For a wind mapping activity and targeted measurement program at 80 sites, this comes to about $300K plus $800K, or a total of $1.1 million. In this case, with higher-quality data produced by the modeling approach, there is also a cost savings factor of 7 to 8, even under the scenario with minimal labor and other costs.

It is likely that in most developing countries the costs of operating a successful wind monitoring program would exceed these estimates. A reasonable "rule of thumb" would be to assume that the cost savings of the mapping and targeted measurement approach is about an order of magnitude (factor of 10) over the extensive wind measurement activity (excluding extra costs of WAsP modeling, etc.).

Comparing the Costs for the SWERA "Requesting Countries"

The total land area (and land area rank in the world) is shown below for each of the pilot countries in Table 1. Table 1 also shows the costs of modeling and measurement programs for wind resource assessment, with less than 100% of the larger countries being assessed. We assume that the governments of China, Brazil, India, and Algeria can identify the priority large regions for wind resource assessment. For example, the Chinese have indicated that the immediate priority is for mapping the near-shore off-shore wind resources, in order to identify large-scale wind power opportunities for supplying electricity to the major population centers on the country's east coast.

Table 1 is the output table from a simple Excel spreadsheet model used to derive the approximate costs of each approach, using the data presented above in this technical note. Results of a sensitivity analysis on the percent of land area to be mapped in the four largest area countries are shown in Table 3. Area percentages ranging from 10% to 100% were used. Table 2 shows the definition for the Central American countries that have requested participation in the project. These have been aggregated into a single land mass for modeling purposes.

Table 1. Comparison of Wind Resource Assessment Costs by NREL Computer Modeling Techniques and Extensive Ground Measurements

World Rank	Country	Total Area (sq. km.)	Survey Area (sq. km.)	Percent Covered	Costs of Modeling	Costs of Measuring
4	China	9,571,300	1,435,695	15%	243,570	5,742,780
5	Brazil	8,547,404	1,282,111	15%	228,211	5,128,442
7	India	3,165,596	474,839	15%	147,484	1,899,358
45	Kenya	582,646	582,646	100%	158,265	2,330,584
79	Ghana	238,500	238,500	100%	123,850	954,000
[87]	Honduras, Guatemala, Nicaragua, ELSalvador	180,135	180,135	100%	118,014	720,540

91	Bangladesh	147,570	147,570	100%	114,757	590,280
92	Nepal	147,181	147,181	100%	114,718	588,724
99	Cuba	114,525	114,525	100%	111,453	458,100
119	Sri Lanka	65,610	65,610	100%	106,561	262,440
		22,760,467	**4,668,812**		**1,466,883 $**	**$ 18,675,248**

ANNEX E: BASELINE SOLAR AND WIND ENERGY RESOURCE DATA AND INFORMATION DEVELOPMENT ACTIVITIES

China

Wind

The China Academy of Meteorological Sciences (CAMS) has developed a national wind power density distribution map. In addition, provinces that are rich in wind energy potential have also been identified. Several detailed wind resource surveys have also been carried in China. With support from U.S. National Renewable Energy Laboratory (NREL) and the U.S. Environmental Protection Agency (EPA), a wind map of Nan'ao Island was developed. Wind mapping activities have also been carried out in the areas of Poyanghu Lake of Jiangxi province, coast of Fujian and Guangdong province in a collaboration between NREL and the State Power Corporation of China (SPCC). Several provincial organizations (e.g., Danbancheng, Xinjiang, Huitengxile, Inner Mongolia, Zhangbei, Hebei) have conducted local wind energy resource surveys, and wind resource databases exist in China to extend regional mapping activities.

Wind energy resource estimation and mapping for Southeast China were conducted with US government and private sector support, with Chinese participation through the State Power Corporation of China (SPCC).

A wind measurement program was initiated to collect detailed meteorological data to evaluate the energy production potential at sites under consideration for future large-scale wind power plant projects. SPCC installed wind measurement stations at 12 locations; one near Shanghai, two in the Poyang Lake region near Lu Shan in Jiangxi, and at sites along the coast in Fujian and Guangdong. Several thousand hours of wind records have been compiled by the 12 systems and the results are providing accurate and reliable data needed for evaluating project energy production potential and economics. The second part of the wind energy assessment program underway involves regional wind resource analysis and mapping. This is an effort to assess overall wind potential in large areas of key provinces and to find good potential wind sites where wind measurement programs are needed.

Preliminary wind assessment and mapping were conducted for two regions in southeastern China. The first region was the coastal area stretching from southeastern Guangdong up to northern Fujian. The second region was centered around the Poyang Lake in northern Jiangxi and included parts of two other provinces, Anhui and Hubei, extending from near Anqing southward to near Nanchang.

Using atmospheric flow models developed by NREL, three regional wind maps, based on the Geographic Information System (GIS), have been developed. Terrain data in digital form was used in the modeling process. Wind and other meteorological data were combined into a very large database drawing from several sources. These databases included: information from 85 selected meteorological stations in the region; surface weather observations from World Meteorological Organization stations in southeastern China available through the National Climatic Data Center in the United States; marine data reported from ships at sea; near shore wind speed estimates derived from wave height measurement taken by satellites using

microwave imaging; and from upper air data sets. Results from the wind mapping show that many sites in the two study areas have good-to-excellent potential.

The most productive sites were found along the coast and on offshore islands especially in Fujian. The study concluded that the coastal areas in Fujian and Guangdong, including off-shore islands and land up to 10 km inland, had wind resource potential of almost 50 GWe. Wind mapping for Nanao Island in Guangdong province has identified many excellent wind sites. The island is the location of numerous wind power plant projects including one plant with ten 550-kWe turbines. Another joint NREL/Chinese study determined the value of large-scale wind power for the North-east grid.

Solar

CAMS has also developed a national solar energy distribution map. NREL in collaboration with CRED has determined in draft form a global monthly horizontal solar radiation from satellite data. As part of the UNDP/GEF-*supported Capacity Building for Rapid Commercialization of Renewable Energy Project,* wind, solar, biomass, and geothermal energy resource data are being compiled in a GIS-compatible database.

Bangladesh

Solar

Measurement of global, diffuse and direct solar radiation has been made at RERC, Dhaka using Eppley equipment. Correlation techniques have been developed to produce solar radiation values with low errors (RMSE: 2-3%). The Bangladesh Meteorological department has 34 sunshine recording stations situated generally in towns and cities. Use of sunshine data from Meteorological department and rainfall data over the country have led to monthly and annual radiation maps. Currently the electronic data collection equipment is not working.

Wind

The Bangladesh Centre for Advanced Studies (BCAS) in collaboration with ETSU, Harwell has measured wind data at 7 coastal stations for one year. Data quality for mean, maximum and minimum speeds as well direction appears to be satisfactory. The Bangladesh Meteorological department has 34 sunshine recording and wind speed measuring stations in towns and cities. Wind data are inadequate for assessing wind electric power potential in the country.

Sri Lanka

Wind

A component of the UNDP/GEF-supported *Sri Lanka Renewable Energy and Energy Capacity Building Project* is under implementation to collect wind and small hydro resource data. As part of the project to develop the wind energy resource data, the Ceylon Electricity Board (CEB) is being trained to use existing wind data and new software to generate wind maps. Also, eight wind measurement stations will be established on an 80-km corridor in the west coast from north to south.

Solar
There are no formal solar resource data available in Sri Lanka.

GIS
Various government and international agencies, NGOs and academic institutions (i.e., Survey department, Forest department, International irrigation management institute, Open University, University of Colombo, etc) are currently using a variety of GIS applications. The Survey department currently uses CD-ROM maps of Sri Lanka and universities use GIS for research work.

Nepal

Solar
A detailed solar radiation mapping is not available in Nepal. The average insolation data that is available for Nepal is from the World Meteorological Organization indicating that Nepal receives 4 to 5 kWh per square meter per day.

Wind
Wind power potential has been estimated for the 12 km corridor from Kagbeni to Chhusang in 1992. For Solukhumbu district in Khumbu region, average wind speed has been determined to be 5 m/s in a study conducted in 1997. The Department of Meteorology and Hydrology has also conducted preliminary surveys of wind energy potential in the hilly regions of Nepal as well as in Terai.

GIS
Several government agencies and universities have had experience in the use of GIS applications for national and district level planning. The primary institutions are the Ministry of Agriculture, Department of Mining, Department of Hydrology and Meteorology, and the Tribhuvan University Department of Geography. There is a UNEP/ GRID Centre in Kathmandu.

Ghana

Ghana has not conducted any detailed solar or wind resource mapping or assessment activities. A very rough general map of annual global insolation has been developed using meteorological measurements from several stations in the country. There is anecdotal evidence of potentially significant coastal wind resources, but no relevant wind resource measurements have been conducted. Ghana could integrate a large quantity of wind electric power into its grid due to the preponderance of high dam hydro-power. At the same time, all of the wind-generated electricity would displace expensive fossil fuels at the margin. The Ministry of Mines and Energy has expressed great interest in having the solar and wind resource assessments conducted for just these regions.

Kenya

There are various studies that have been carried in Kenya over the years. However, most of the documentation is not easily available. Some also like the UNEP-IPAL were incomplete and hence inconclusive. Wind Technology Assessment study was carried out by the World Bank and UNDP, the report of the study cannot be traced. UNEP/IPAL under the Integrated Programme on Arid Lands (IPAL) did some detailed data collection in Northern Kenya. However, the data was

not processed and hence inconclusive. SWD-Steering Committee on Wind Energy of the Netherlands did a comprehensive study on wind development in Kenya. Though this is one of the most current studies, the report is available with some NGOs but could not be easily accessed. The Ministry of Water Development did a comprehensive study on sites for PV pumping in Kenya. This study was based on synthesised data from Kenya Meteorological department (KMD)

Currently meteorological data collection, processing and storage is done by the Kenya Meteorological Department. The Department has 35 stations spread all over the country. However, the information gathered is not adequate to resolve. Detailed analysis is possible by incorporating additional stations. These additional stations will help give horizontal distribution. Previous studies have not been able to give detailed resolutions due to sparse station network. Previous studies have shown strong existence of two strong wind currents; the Turkana Jet and the Eastern African Low Level Jet.

The study currently being conducted by MOE and KMD is going to concentrate only on "high potential areas" that are within reasonable distance to the grid. As additional stations are needed it will be necessary to install temporary manual and permanent automatic stations. Students of Science Clubs will read the temporary and manual stations. This we thought should be a way of inducing them to wind measurement and hence renewable resources education campaign. Currently the KMD is assessing the areas under which additional stations, both temporary and permanent can be installed. The data acquisition equipment can be procured and installed.

Wind installations are cost effective in Kenya, Ngong Hills has an installation that paid back in three years. In the north average wind speeds of 7 m/second indicate very good resource for remote communities located there. There are many escarpments –notably the rift valley where wind speed is significantly accelerated and many of these locations are of interest. Kenya Ministry of energy is updating a wind map for Kenya and hopes to attract investment in wind energy under the recently past energy sector reform bill.

Kenya is a solar hot spot especially north eastern areas. There are also some electric grid lines extending to the arid northern region suggesting that solar thermal electric is a good possibility. Due to recurrent drought conditions, Kenya's hydro electricity supply is currently unreliable and cannot meet current demand (summer 2000). Solar presents a good opportunity for electrification of remote areas.

Ethiopia

In Ethiopia the National Meteorological Services Agency (NMSA) is responsible for installing, collecting, and archiving of meteorological and climatological data. It is also responsible for providing meteorological services including public weather forecast and conducting meteorological research.

In the 1980's the NMSA had over 12 meteorological stations where data on solar radiation had been recorded over a decade. Moreover, sunshine duration hour's data had been available for over hundred meteorological stations. Wind speed and direction has also been systematically

recorded at Airports. The only comprehensive wind and solar energy resources data is prepared by CESEN/ENEC[6] study using available data from the NMSA.

Currently the NMSA administers and runs about 630 meteorological stations of various classes nationwide. About 125 stations are in the first class category. Most of these stations have Actinographs and Campbell Stacks Sunshine recorders. These first class stations are also equipped with anemometers and wind-vanes, which measure wind runs and wind directions respectively. There is only one station located in Addis Ababa, which measures global and defuses radiation directly. The Agency has primary Meteosat and NOAA satellite data reception systems. Rainfall and vegetation monitoring over the country is done using data from these satellites.

However, detailed and localized resources data on wind and solar energy is not presently available. Consequently, lack of these data has remained one of the major constraints in the development of winds and solar energy resources.

Wind

The CESEN/ENEC study used wind speed and direction data made available by the NMSA. Since 1971 and up until 1986 data on wind speed and direction has been systematically collected by NMSA in 39 stations, most of which, are located at airports or in specific locations that are not particularly selected for wind resources assessment. NMSA has produced wind speed and direction map on monthly basis in 1979. Since 1986, the number of stations where wind data is collected had been increased.

As indicated above the scope of the measurement of wind data is not meant for resources assessment and the available information had been limited to specific sites and data sets. Such data thus could only be used to evaluate primary gross wind energy resources and wind distribution in the country. For example, wind speed is available for 6:00, 12:00 and 18:00 hours, and no data is recorded in between. The measurement is also taken at height lower than 10 meter (the accepted standard).

Moreover, the fact that in Ethiopia only monthly average wind speeds and a very small number of stations were available had made the extension of points-data wind resource measurements to the whole country very difficult. And also wind energy is highly variable over terrain (as a function of topography and other artificial barriers) makes extension of points-data wind resources, even more difficult and reduces its reliability.

However, based on the available data CESEN/ENEC study has estimated the wind energy resources potential as an indication of regional distribution of wind resources within the country with a broad category of "greater" or "lesser" potential.

The study shows that in the western part of the country the wind is calmer at less than 3.5m/s gradually increasing to an average figure of 3.5 to 5.5m/s as one moves to the east. Wind speed in excess of 5.5m/s is found in location that is farther out to the eastern boarder of the country.

[6] CESEN/ENEC, 1986 Main Report. Co-operation agreement in the Energy sector between the Ministry of Mines and Energy and the government of Italy.

The respective energy density per square meter of turbine swept area for the above three major categories is 500, 500 to 1500 and an excess of 1500Mcal/m2.

Solar

Solar radiation energy for the country, just like that of wind energy, had been prepared by CESEN/ENEC based on data made available by NMSA and using available data from FAO. National Meteorological Services Agency had a map showing duration of sunshine hours on a monthly basis in 1979. However, solar radiation data collected by the NMSA, be it in whichever form, had been available only as a photometer data and had been costly and time consuming to process in the form required. Thus, lacking data on direct measurements, the estimation of radiation had been based on secondary data.

In particular the radiation values for selected towns, station and the country as a whole were derived from sunshine duration data collected at the 142 stations available at the time of the study. The CESEN/ENEC study applied the Angstrom and Schuepp relations to estimate total radiation from available sunshine hour data. The point data estimated at the meteorological stations is then extended to the whole of the country using classical correlation techniques based on altitude above sea level.

The CESEN/ENEC study shows that most parts of Ethiopia receive fairly high solar radiation throughout the year. For Ethiopia as a whole, the average daily radiation reaching the ground is 5.2 Kwh/m^2. The radiation reaching the ground, however, varies significantly. The minimum annual average radiation is estimated to be 4.5 Kwh/m^2 in July (the main rainy season) to a maximum of 5.55 Kwh/m^2in February and March.

The CESEN/ENEC study has also documented and provided radiation data for a number of towns and meteorological stations, and had also produced Atlases.

GIS

The Ethiopian Rural Energy Development and Promotion Center has not yet introduced nor has any experience in application of Geographic Information System (GIS). However, it has recognized the importance of employment of GIS in locating and determining the different energy resources within the country.

GIS is used by some Government Institutions such as Ministry of Water Resources, the Woody Biomass Inventory and Strategic Planning Project (Ministry of Agriculture and Natural Resources) and the Ethiopian Mapping Agency. Among these the later two are actively emploing GIS in their resources assessment and mapping activities. Also the NMSA has some experiences in GIS for satellite data handling.

The Geological Surveys of Ethiopia (Ministry of Mines and Energy), has established GIS facilities about five years ago through Eastern and Southern Africa Mineral Resources Development Center (ESMRDC) which was latter called SEMIC. Member countries were expected to develop regional mineral resources map. Addis Ababa City Council Bureau is currently using GIS for locating different characters such as residential houses and roads.

Latin America and Carribean:

Brazil

Solar

Several Brazilian research institutions and universities carry on intensive research of solar radiation modeling and radiative transfer studies, although most of them directed to climate research. The University of São Paulo through its Institute of Astronomy and Geophysics (USP-IAG) has been actively working on the parameterization of the radiative properties of aerosols and clouds aiming at the improvement of climatic models. INPE-CPTEC has also a radiative transfer model GL 1.0 that employs GOES-8 VIS and IR images to provide daily, weekly, and monthly horizontal global solar charts with approximately 12 km X 12 km ground resolution for some selected regions of Brazil (south-southeast and Northeast) for climatological purposes. The LABOSLAR at the University of Santa Catarina has developed under collaboration with INPE and GKSS (Germany) the BRASIL-SR model that is currently used in assessing the solar energy resources of Brazil.

The first Atlas of Surface Solar Radiation for Brazil by satellite technique was issued in 1998 under a collaboration agreement between UFSC-INPE-INMET. It provides the most comprehensive evaluation of the surface solar radiation on a horizontal plane for Brazil based on a ground-validated spectral physical radiative transfer model (the BRASIL-SR) that uses satellite data as input. Daily, monthly and annual means of global horizontal radiation data were provided at a resolution of 0.5^o x 0.5^o along with information on variability and climatic zones. The algorithm employs digital satellite from the GOES-8 data in the visible channel (0.52 to 0.72 μm). This is located at about 75^oW at the equator, thus providing excellent area coverage for Brazil. INPE collects raw satellite data at 12GMT, 15GMT, 18GMT, and 21GMT through its division of Environmental Satellites – INPE/DSA in Cachoeira Paulista at an 8 km x 4.6 km horizontal ground resolution at satellite nadir. A new version of this model was developed by INPE and is now being validated. It incorporates several improvements: 1) improved cloud screening process that uses the IR region of the spectra in addition to the visible portion of the earlier version; 2) better parameterization of aerosols; 3) estimation of diffuse and direct beam radiation; 4) finer space resolution (0.12^o x 0.12^o); 5) finer time resolution (hourly); and 6) extended area of coverage (the whole Latin America and surrounding oceans).

As far as solar data from ground stations are concerned, the CRESESB (The Brazilian Solar and Wind Energy Reference Center) has made available trough the web a software that provides the user an access to a databank of daily means of global horizontal solar radiation for the Brazilian territory based on the interpolation of 350 ground stations from the CENSOSLAR-1993. The web-search is made by entering the geographic data for the point of interest and the output are the daily means for 12 months of solar radiation in kWh/m^2. This data bank has been extensively used for the implementation of the PRODEEM project. On this same line, the University of Pernanbuco, through its Group for Alternative Energy Research (FAE) has published in 1996 a Solar Atlas for Brazil from an interpolated compilation of nearly 30 years of ground data from the INMET network of actinographs an pyranometers (about 571 ground sites). This work has a premium value mainly as historical archive for further inter-annual variability statistics of solar radiation.

The Laboratory for Solar Energy (LABSOLAR) from the Federal University of Santa Catarina has great expertise in the solar energy research, applications, and energy resource evaluation

both by conducting ground measurements in several sites of Brazil and by model estimation. The LABSOLAR has two BSRN/WMO (Baseline Surface Radiation Network – World Meteorological Organization) sites, one in Santa Catarina, South of Brazil and other in Balbina, Amazon region North of Brazil. Both are first grade solar radiation stations that produce direct, global and diffuse radiation data on the horizontal plane for the visible and infrared solar spectral range, along with several meteorological variables of interest. The LABSOLAR control four other radiation sites in the state of Santa Catarina and will soon set up three additional sites in the Amazon region in collaboration with the German government. These stations are mainly used as validation sites for the BRAZIL-SR radiation transfer model that has been developed jointly with INPE.

Among other facilities directed to the research and technological development of solar energy projects, it is to mention the complete facility for calibration of pyrheliometers and pyranometers to BSRN standards.

In a partnership with INPE, LABSOLAR organizes and hosts the historical archive of METEOSAT (1994-95) and GOES-8 (1996 to present) satellite images for Brazil in the visible and infrared spectral range. In 1998, LABSOLAR has issued the first satellite-derived Atlas of Solar Radiation for Brazil in collaboration with INPE and INMET (Brazilian National Institute of Meteorology), and is preparing an updated version of the Atlas to be issued in October 2000.

Wind

Wind assessment in Brazil started 12 years ago with several preliminary resource assessment programs in specific locations. Those programs, which had been conducted by the Brazilian Wind Energy Center – CBEE and/or state utilities were based on the installation of modern wind data loggers, data collection and analysis through the simulation of the wind climate using a microscale atmospheric model (e.g. Wasp/Risø). Most focus has been put on the state of Ceará mainly because it was the first one to carry out precise and reliable wind data collection. However it was not only in the coast of Northeast region that windy sites were identified. In Minas Gerais, 1,000km from the coast, a 1MW wind farm is located on a 7m/s site. In the southern part of Brazil, state of Paraná, annual averages of 7.5m/s have been reported.

In 1998, CBEE has published the Wind Atlas for the Northeast of Brazil (WANEB) with support of the National Regulatory Agency of Electricity, ANEEL. The objective of the WANEB is to provide a methodology for wind power assessment of large areas in Brazil. It uses high quality surface and upper air data as inputs of both mesoscale and microscale models of the atmosphere to characterise the wind climate of a region. CBEE is currently working on the Brazilian Wind Atlas project. The main objective of this new project is to select and process representative high quality wind data and elaborate wind resource maps with 30-20Km resolution covering the entire country, with finer resolution (1km) on selected windy areas. The methodology is based on mesoscale model integrations (MM5 model) of a complete set of large-scale atmospheric states, resulting on a climatically representative (gridded) wind data. Local scale influences were computed only for grid points surrounding reliable ground stations, using the microscale model WAsP. CBEE is running MM5 since 1999 and trying to calibrate the model for the Brazilian Climatic framework. The main input data comes from the global climate data of NCAR/NCEP reanalysis project. CRESESB/CEPEL have made available trough the web a large archive mostly

for the Northeast region based on wind data (ground data compilation) from several Brazilian institutions (INMET, COELBA, COELCE and CEPEL).

The electric power company COPEL, has released in 1999 a detailed wind map for the state of Paraná. This work was conducted by the Camargo Shubert Wind Energy and was based on the extrapolations to 50-m high winds by WindMap methodology around ground monitoring stations. The final maps were generated on a 2 km x 2 km resolution. A wind atlas for Brazil is also being developed by ELETROBRÁS/CEPEL. The project, with a national consulting partnership linked to the TrueWind Solutions (US), aims to create a georeferenced wind Atlas for Brazil with a 1 km x 1 km ground resolution plus annual statistics, Weibull factors and power density information. Validation of the maps against other methods would increase confidence in the methodologies.

The Brazilian Wind Energy Center (CBEE) was created in 1996 as an independent institution managed by the staff of the Wind Energy Group of the Federal University of Pernambuco. Its main objectives are: a) contribute to the development of wind power technology; b) act as an information center for wind energy; and c) provide support for the wind industry in Brazil.
The activities of the CBEE are divided into three fields:

- Research and development
- Projects and consultancy
- Education and capacity building

The CBEE Test Station, inaugurated in June 1996 and located in Olinda, state of Pernambuco, has about 500 k$ worth in equipment and infrastructure including two experimental wind turbines, one with rated power of 30kW (for grid connection and stand alone applications as well as hybrid systems) and another rating 300kW (for wind farm application), and state-of-the-art data acquisition system (hardware and software). The Test Station supports researches and activities in the following areas: power performance tests/verification, study of natural aerodynamics, structural dynamics and aeroelasticity, power quality measurements, demonstration and information, training, Brazilian standards, certification of wind turbines, hybrid power systems. Part of the research activity and project development of the CBEE is carried out in cooperation with international institutions (RERL/University of Massachusetts at Amherst/USA, Risø/Denmark, CREST/England, CIEMAT/Spain, INETI/Portugal, and CRES/Greece). The cooperation agreements include also exchange of researchers and joint PhD projects.

The Electric Power Research Center (CEPEL) is a research center linked to the ELETROBRÁS and develops equipment, power generation, transmission, and distribution technologies, as well as techniques for the rational use of electric energy. The CEPEL's Sérgio Salvo Brito Center of Reference for Solar and Wind Energies – CRESESB is the link to the national solar and wind resource assessment and its main objectives are to promote the development of solar and wind energy through demonstration and diffusion of knowledge in this area as well as by stimulating the implementation of new projects and studies involving the efficient use of alternative energies. Aiming at the assessment of the solar and wind energy resource in Brazil, CRESESB has created a databank with ground data compiled from the whole national territory and from some neighboring countries. This databank can be assessed on line through the web and is geographically referenced through a GIS platform.

GIS

GIS products and facilities can be found widely in Brazil. Several government institutions, universities, and private companies use primarily ARCINFO/ARCVIEW, IDRISI and SPRING platforms. SPRING, for example, is a national state-of-the-art GIS and remote sensing image processing system with an object-oriented data model which provides for the integration of raster and vector data representations in a single environment. SPRING is freeware product of the Brazil's National Institute for Space Research (INPE). It is a share-free software that has been used for important projects in Brazil such as satellite imagery of the deforestation in the Amazon region. Besides being fully compatible with archives generated by the standard ARC INFO and IDRISI, the SPRING main features are: an integrated GIS for environmental, social-economical and urban planning applications; a multi-platform system, including support for Windows 95/98/NT, Linux and Solaris; a widely accessible freeware for the GIS community with a quick learning curve and; it is a mechanism of diffusion of the knowledge developed for the INPE and its partners with the introduction of new algorithms and methodologies.

As for the GIS data base of interest for the assessment of solar and wind energy resources in Brazil, there are several national hosting and supporting institutions such as:

Brazilian Electric Sector (ELETROBRÁS/CEPEL/CRESESB): Power sources, electricity generation, transmission, distribution, consumption, market, and energy conservation

Brazilian Agricultural Research Corporation (EMBRAPA): Environmental information, agroindustry, and regional development.

Brazilian National Institute of Geography and Statistics (IBGE): Census, population statistics and distribution, agricultural data, industries, transportation, geodesy and cartography, territory organization, natural resources and environment.

Brazilian National Institute of Space Research (INPE): Satellite data, weather and climate products, atmospheric soundings, vegetation and ground cover, geology and topography, dynamics of land use in the Amazon region.

Nicaragua, Guatemala, Honduras, El Salvador

Status of resource assessment

Ongoing programs for wind and solar energy resource assessment at governmental level are insufficient. Mostly private companies are engaged in such activities. No known wind atlas exists for this region. As for solar radiation assessment, pyranometric data are known to be available for Honduras (8 sites) and Costa Rica (17 sites), and some effort has been given to derive solar maps from interpolated ground sites with help of RISOL (The Iberian-American Solar Network). World Bank is initiating a PDF for Rural Wind Development in Nicaragua. SWERA will contribute maps to assist them in targeting measurements and investments.

Cuba

Wind

The Institute of Meteorology of Cuba, under the Ministry of Science, Technology, and Environment, operates a network of 65 meteorological stations evenly distributed over the country. This network produces 24-hour measurements of wind speed and direction, normalized to 10 meters above the station. Observations have been conducted for 30 to 40 years. Only three of the stations are located in mountainous areas. More than 70% of the stations are located in rural areas that are plains or landscape with lightly irregular relief. The quality of the observations is assured through systematic monitoring of the stations and ongoing data validation.

An unpublished wind atlas of Cuba was prepared in 1995. Calculations included the effects of topography on air flow, and the effects of heat and humidity on the vertical wind speed profile. For the preparation of the atlas, data from 59 meteorological stations were used, with periods of 5 to 10 years (1977-1986). The topographical environments of the stations were analyzed within a 1 kilometer radius. Statistics and wind climatology of the 59 stations are available. A map of wind potential of Cuba was prepared by the Center of Physics of the Atmosphere. Institute of Meteorology of Cuba.

Since 1991, with the aid of German and Spanish NGOs, Cuba has had a program to characterize the wind resources at 24 locations, including five sites at some small islands at the northern coast. Comprehensive measurements are taken at 10 and 20 m height, with data processed using commercial software.

Solar

For solar radiation resource assessment, there are two type A1 sites, and five A2 sites, operated and maintained by the Institute of Meteorology of the Ministry of Science, Technology and Environment of Cuba. The database of solar information dates from 1969. Both stations measure direct, diffuse, and global irradiance, and short wave reflected irradiance. The Type A1 stations also measure several other meteorological and atmospheric parameters. The A1 stations conduct manual and automated observations. Control measurements and calibration of the sensors are also regularly performed. The A2 stations conduct the measurements manually. The network of stations of the Institute of Meteorology has maintained solar measurement data since 1969.

The heliographic network dates from 1961. The net is equipped with Cambell-Stoke type instruments. Since 1991, solar resources have been characterized for almost 40 stations throughout Cuba. The Center of Physics of the Atmosphere of the INSMET has prepared maps of annual average sunshine and solar irradiance at a scale of 1:3 million. The responsible institution is the Group of Solar Radiation of the Center of Physics of the Atmosphere of the Institute of Meteorology of the CITMA.

GIS

The Institute of Tropical Geography of Cuba is the national institution most heavily engaged in GIS-related activities. The Institute has extensive computer facilities, and experience with a wide range of GIS software. The SPRING Geographical Information System from INPE-BRAZIL is in use with the cartographic bases of Cuba in the Institute of Meteorology. No Satellite imagery and sources are available at this Institute.

Annex F: Implementation Arrangements – Agency Roles

Body	Function
UNEP/ DTIE (Project Manager)	Manage and co-ordinate the SWERA agencies Promote SWERA products to governments and investors Link the SWERA activities to the Sustainable Technology Alternatives Network
Steering Committee	Advises UNEP DTIE on management of the project
SWERA Technical Support Agencies NREL, INPE, SUNY, DLR, Risø, TERI, UNEP/GRID	Implement the mapping, database, and GIS activities
Regional Co-ordinators (TERI, INPE)	Co-ordinate and or assist with regional country activities
Country partners	Execute nationally orientated assessment activities and promote alternate investment opportunities
Other stakeholders, AWEA, ISES, EWEA, investors, GEF Implementing Agencies, GTZ	Facilitate use of data; project financing initiatives

Institutional Roles and Responsibilities

Institution	Solar Resource Assessment	Wind Resource Assessment	GIS and other activities
UNEP/DTIE			Responsible for overall project implementation
UNEP/GRID			Solar and wind resource data and limited information associated with the resource data, advice on tool development and other applications
NREL	Medium-resolution and high-resolution solar mapping/assessment	High-resolution (1 km) wind resource maps	Preparation of GIS Toolkit for use of solar and wind resource data by host country agencies. Training of regional agencies in GIS applications of solar and wind data sets.
Risoe		5-km resolution mapping of selected regions, to increase information and confirmation in complex terrain regions; training in the use of WaSP for site validation of NREL / Risoe mapping	

INPE	Medium resolution and high-resolution solar mapping of South America, in collaboration with LABSOLAR, NREL and SUNY.	Model cross-comparison in selected areas in collaboration with CBBEE	Hosting of regional workshops for participating and interested countries, training of country participants in use of the solar data and in GIS Toolkit use
SUNY	High-resolution horizontal irradiation solar mapping and technical assistance		
DLR	Mapping of Direct Normal Incident (DNI) solar radiation for selected regions of Africa		
TERI	Acquisition and interpretation of solar radiation-related data from INSAT	Training of host country agencies in interpretation of wind maps and data, and in preparation of wind atlas text; Application of WAsP for site-based wind resource validation against model-derived wind maps	Hosting of regional workshops for participating and interested countries, training of country participants in use of the solar and wind data, and in GIS Toolkit use
National Collaborating Agencies	Quality control and reanalysis/ conversion of existing ground data sets for validation and to provide time series information	Quality control and reanalysis/ conversion of existing ground data sets for validation and to provide time series information	National application of SWERA tools and information to develop and promote alternate energy development scenarios

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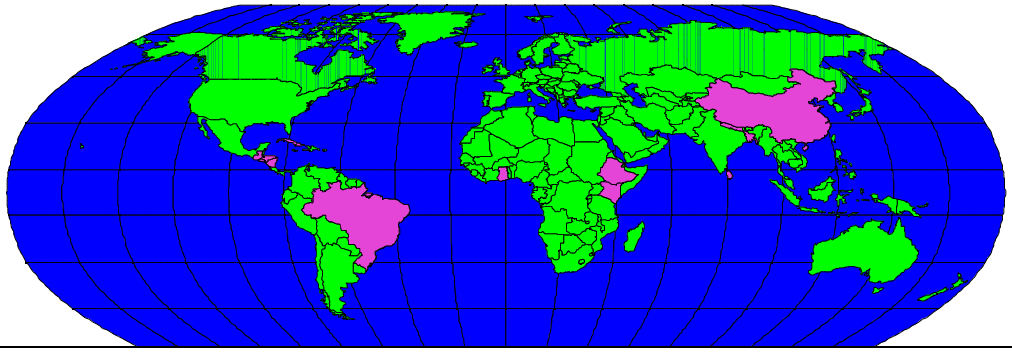
SWERA Pilot Coverage



Countries Cuba, EL Salvador, Honduras, Nicaragua, Guatemala, Brazil, Ghana, Ethiopia, Kenya China, Sri Lanka, Nepal, Bangladesh

Regional Solar Maps to include all of Latin America and the Caribbean, all of Africa, China, India, Sri Lanka,Nepal, Bangladesh, and parts of South East Asia

ANNEX G INCREMENTAL CAPACITY BUILDING WITHIN COLLABORATING AGENCIES

The SWERA project focuses on removal of information barriers through satellite and computer modeling techniques, and building the capacity in the national collaborating agencies to use this information and contribute to the output of the project. Capacity building is therefore limited in scope and extensive follow on activities will be needed. Capacity will be increased incrementally from each country's baseline where they can become sustainable.

Use of the information is the most critical barrier. Proficiency in the use of the information and tools in activity 4 are therefore the most important. For advanced countries and especially for the regional agencies, access to GIS datasets that can be used in the more sophisticated GIS applications will allow them to expand the use.

Knowledge of wind measurement is also crucial to the national capacity. Since only a core capacity will be established during the national activities, additional funding for pre-feasibility studies and expanded training will be necessary before investment. The firm understanding of the wind data by national collaborating agencies will be able to support further development of national policies and plans. Knowledge of solar measurements will also be beneficial.

Where countries/regional agencies already have measurement capacity and assessment capability the incremental effort will be redirected to allow them to perform assessment activities them selves. INPE-Labsolar will perform a significant portion of the Latin American mapping activities. CBEE will work with NREL and Risø to refine their 30km resolution wind map in Brazil. TERI and DLR can perform solar mapping for Asian countries using a combination of METEOSAT5 and INSAT data. During project initiation, the ability of agencies to perform additional assessment tasks will be investigated. The technical review activities in solar, wind and GIS will allow formulation of detailed responsibilities for assessment activities that meet the information barrier removal goals within the prescribed incremental budgets for the pilot project and build on the existing capacities in developing countries.

In addition, the Technology Transfer Network, GTZ TERNA Program, World Bank and UNDP national projects will be linked to this assessment work to carry on further technical assistance leading to further investments and replication.

ANNEX H: MAPPING ACTIVITIES BY COUNTRY AND REGION

Targeting the SWERA Wind Maps

The actual targeted areas will be finally agreed with the respective national collaborating partners during the review exercise at the start of Activity 2.

Central America:

Nicaragua, Guatemala, Honduras, and El Salvador are likely to have very good potential for wind if their resource has any similarity to Costa Rica. (Tejona shows annual average wind speeds of 11 m/s@ ~15m). This map will demonstrate cost savings in the execution of regional maps as opposed to individual maps, country by country. The four countries are anticipated to work together, further reinforcing cost-effectiveness opportunities.

NREL Wind Resource Assessment and Mapping System (WRAMS) for a block encompassing all countries is proposed. Risoe's survey of wind atlases shows no previous activity for this region and existing ground measurements are expected to be minimal. The potential for removing a resource information barrier is very high. The mapping spillover may be able to pick up wind measurement locations in areas of adjacent countries. Otherwise, the ocean surface roughness wind speed data can also be used. Due to hilly terrain, additional mapping with the mesoscale model (KAMM) will be valuable. A pool of WAsP trained experts can be established for the region as a whole supporting sustainability of the expertise. Subject to further discovery, the countries may benefit from a combined approach to wind energy development, especially if they intend on having a common distribution grid.

WRAMS 120 k$
KAMM - 2 areas 68 k$
Risoe WAsP training (part of a regional activity)
Translation, participant travel and accomodations from regional budget
Technical Support CBEE /Risoe
National MoEs 88 k$ (22k$ each subject to needs/opportunities)

Cuba

Cuba has a relatively large number of measurement stations, the information has been converted into a wind atlas although the number of stations in the mountainous ares of interest were few (3). Interest in developing wind potential in these areas is significant. The combination of Capacity building in the use of WAsP and the targeting of further measurement activity by WRAMS map will demonstrate the impact of SWERA effectively.

NRELWRAMS 80 k$
Risoe WAsP training (part of a regional activity)
WAsP training session to require Spanish translation from regional budget
Technical Support INPE (CBEE) /Risoe
Agencia de Ciencia y Tecnologia 36 k$

Brazil

Brazil has significant and well advanced wind energy resource assessment activities, as well as having contracted TrueWind/ Camargo – Schubert Engineering Limited to map the states of Parana, Santa Catarina, Mato Grosso do Sul, Rio Grande do Sul, and others, with a mesoscale model. More than 60 measuring towers (at least 30 with two anemometers, at heights of 30 and 50 m) were installed for validation of wind velocity distribution mapping. INPE/CPTEC has a strong infrastructure for upper air data and other weather/climate and satellite products. CBEE is developing their capacity with another Mesoscale Model MM5. Expansion of their capacity through technical exchange and cross comparison will provide the best cost/benefit to the SWERA project. An appropriate area for resource potential and cross comparison of techniques can be identified during project initiation. CBEE and Risoe have made some highly localised comparisons between KAMM and ground measurements. CBEE is fully capable with WAsP.

NREL WRAMS and technical assistance in upper air data selection, preparation	100 k$
KAMM	34 k$
CBEE	139 k$

Regional training is proposed to take place at CBEE Recife, Brazil. National trainee's travel is in the INPE budget 35 k$, WAsP training/software provided through Risoe, technical backstopping provided by CBEE.

China

China has had NREL WRAMS maps developed for part of the coast and an inland lake island both showing significant resource. Under the US EPA funded TCAPP work, China developed a proposal calling for wind mapping targeting areas near the coast and including offshore wind potential. NREL WRAMS should expand on the existing maps taking advantage of any preparatory work done for those maps and extend the maps within the resources available. US EPA and other agencies should be approached in order to attempt to reach China's requested mapping effort. The offshore potential will not require high resolution modeling and can use KAMM at 10 km resolution.

NREL WRAMS	200 k$
KAMM	34 k$
Risoe KAMM low res ocean to coast	34 k$
WAsP training session provided by Risoe	
Technical support Risoe	
State Power Corporation of China	45k$

South Asia: Nepal, Bangladesh, and Sri Lanka.

Concerns have been raised as to whether Bangladesh has a large enough potential for wind to justify significant effort. Previous GTZ measurements and analysis of upper air data by CWET India do not show this area as having good enough (>7 m/s) resource for grid connected power. There is reason to believe that for smaller independent systems near the coast, wind is more attractive than solar PV and current investments could be optimised. Many of the best wind potential locations in Nepal are too far from the electricity grid. A cost constrained area near Kathmandu may be considered. Bangladesh can be provided a KAMM only map from the ocean

inland. Off shore wind potential may be of interest. Sri Lanka has a significant amount of wind measurements. Further investigation is required.

WRAMS Nepal	100k$
WRAMS Sri Lanka	75k$
KAMM Nepal	34 k$
Bangladesh from the ocean to coast	34 k$
TERI technical backup	22 k$
U of Dhaka	26 k$
Centre for Energy Studies	27 k$
National Engineering R and D Centre	27 k$

Risoe WAsP training session will take place in Delhi, travel provided through TERI except Kenya who may also participate - travel provided by UNEP.

East Africa: Kenya and Ethiopia

Ngong Hills near Nairobi has demonstrated good wind potential. The volcanic formations and the Rift Valley produce topographic features of interest for wind potential. The open plains area of the north also has good wind potential and needs remote rural electrification. Both of the countries are proposed for mapping as one block.

NREL WRAMS	240 k$
KAMM	68 k$
WAsP training session (South Asia or Copenhagen)	
Technical support Risoe	
Kenya Ministry of Energy	29 k$
Ethiopian Energy Development Centre/ National Meteorological Service	29 k$

Ghana

Ghana is expected to have interesting wind potential at the coast. Some measurements are taking place. Load centres like Accra and the electrical grid are both near the coast. The ECOWAS is attempting to develop a wind atlas for the region. The Ghanaian collaborating agency will be requested to liase with them for possible expansion of the mapping exercise at a later date and to obtain mutual benefits of both activities while mapping Ghana.

NREL WRAMS	100 k$
WAsP training session (Recife or Copenhagen)	
Technical support Risoe	
Ghana Ministry of Energy	29k$

PROPOSED PLAN FOR SOLAR RESOURCE ASSESSMENT

Medium Resolution maps will be generated for all of Latin America and the Carribean, Africa, and a block of Asia including China, India, Nepal, Bangladesh, Myanmar, Sri Lanka and South East Asia.

The pilot phase of SWERA involves 13 countries located in five distinct regions: Central America/Caribbean, South America, Africa, China, and South Asia. A fundamental technology for developing high resolution solar maps for countries within each region is the use of geostationary satellite data. Because the different satellites have somewhat differing data collection and dissemination protocols, the choice of methodology for high resolution mapping within each region may vary somewhat. Because of this situation, a separate medium resolution technique which uses a consistent approach worldwide is also being used to provide a reference data base. In addition, a low resolution technique, being made available to SWERA by the NASA/Langley Research Center, uses a singular worldwide technique that also forms a reference data set.

Central America/Caribbean:
Nicaragua, Guatemala, Honduras, El Salvador and Cuba are likely to show excellent solar resources. Currently, the major solar energy application in this region is the use of small PV systems for home and small commercial activities in regions removed from the electricity grid. Current solar data in this region is very limited, with very few direct measurements, although more extensive measurements may be available in Cuba than in Central America.. Most of the current information is based on conversion of hours of direct sunshine to estimates of daily total global horizontal solar radiation. Studies have been published for individual countries, and a very coarse solar atlas for the region was produced by OLADE in the 1980s. For SWERA the four Central America countries are anticipated to work together, providing opportunities for cost-effectiveness in high resolution solar mapping and assessment.

The NASA/Langley data base that will be available to SWERA provides daily and monthly average global horizontal solar resources for approximately a 10-year period on a 280 km grid (resampled to 100 km). Future upgrades of this data set will offer true 100-km resolution products.

NREL will run the medium-resolution Climatological Solar Radiation (CSR) Model for the region encompassing Central America and Cuba. The model has already been run once for an earlier study, but since that time improvements in the modeling approach, and improved input data, have been identified. Thus, the cost for running the CSR model in this region will be lower than in other regions. The CSR model provides monthly average daily total global horizontal, direct normal, and diffuse solar resources on a 40-km resolution over a seven-year period (1985-1991). Algorithms will also be provided to allow the global horizontal resource data to be converted to calculate the resource for various flat plate orientations.

NREL will also develop long-term time series data by using the surface meteorological data available from the DATSAV2 archive and a solar model. An average of six stations per country will be analyzed for the Central America/Caribbean region. For any given region, the DATSAV2 stations will be identified and the quantity and quality of data for each station will be assessed. For stations meeting selection criteria, any erroneous or missing data will be filled to create serially complete hourly input data sets. Solar radiation data is then modeled using these hourly data sets to create a multi-year file of solar radiation and meteorological data. From the multi-year file, Typical Meteorological Year (TMY) procedures are used to create a TMY.

SUNY/Albany will run its high resolution model for the four-country Central America region and for Cuba. This model provides hourly, daily, and monthly global horizontal, direct normal, and diffuse solar resources at a 10-km resolution for a three-year period. Imagery from the GOES E and W geostationary satellites is used as input.

NREL/CSR	$25k
NREL Time Series	$30k
NREL Cross-model validation and regional support	$28k
SUNY/Albany	$88k
National MoEs	$82k

Brazil

Brazil has significant and well advanced solar resource assessment activities. LabSolar has completed a medium resolution (50-km) solar map of Brazil, and the capacity exists to produce a high-resolution (12- km or less) map. The medium resolution map will be cross-compared with the medium resolution CSR map to be developed by NREL . The domain of the CSR map will be the entire South American continent.

INPE will develop a high resolution map for Brazil covering the period 1997-present. Output from this map will be cross-compared with both the SUNY/Albany and the DLR high resolution mapping techniques over NE Brazil. Cross-comparison studies of the INPE maps with the CSR and NASA products will also be made for the Amazon region.

NREL will also develop long-term time series data by using the surface meteorological data available from the DATSAV2 archive and a solar model. Approximately 15 stations will be chosen for this analysis.

NREL/CSR	$75K
NREL Time Series	$15K
NREL Cross-model validation and regional support	$15K
INPE High-res	
SUNY/Albany	$70K
DLR (NE Brazil)	$35K
LABSOLAR Brazil	$300K

South Asia: Nepal, Bangladesh and Sri Lanka

The NREL/CSR model will be run for the entire south Asia region to provide medium-resolution coverage. NREL time series model will be run for approximately 25 stations in the 4-country region.

Concurrent three-year data sets for both the Meteosat 5 and the INSAT satellites will be acquired and merged to provide high spatial (INSAT) and temporal (Meteosat 5) resolution. The SUNY/Albany-DLR high resolution model will be run for the region using this merged data set.

TERI will develop their own high resolution modeling capability to provide further services in the region.

NREL/CSR	$ 75k
NREL Time Series	$ 25k
NREL Cross-Model Validation and Regional Support	$ 15k
SUNY/Albany	$ 30k
DLR (Meteosat data: $160K; technical Support: $20K)	$180k
TERI (INSAT data: $60K; technical Support: $10K)	$ 70k
National Agencies	$ 58k

China

NREL has made a preliminary medium resolution map of China using the CSR model, but this was a very preliminary calculation. The model will be re-run for this region using updated input data sets.

Currently the plan is for the SUNY/Albany/DLR high resolution model be run for China using Meteosat5 data. In addition, CRED may seek to acquire INSAT or GMS data and develop their own high resolution modeling capability; this still requires further investigation. DLR will support a recommendation on the use of Meteosat/GMS compared with INSAT. The complete coverage for INSAT is shown here. Cost of data acquisition for this entire zone is very high, so TERI will investigate the possibility of acquiring a subset of this zone that includes China. Cost is estimated at $60K, and is shown below. Should high resolution model results using both Meteosat and INSAT over China be accomplished within the SWERA time frame, cross-model validation studies will also be undertaken by the collaborating agencies.

NREL/CSR	$75K
NREL Time Series	$15K
NREL Cross-model validation and regional support	$15K
SUNY/Albany	$15K
DLR (meteosat data: $40K; support $20K)	$60K
TERI(INSAT data, estimated)	$60K
CRED	$37K

Kenya

The NREL/CSR model will be run for the entire region of Africa that includes Kenya, Ghana, and Ethiopia (the entire continent). Although the model has been run for northern Africa to produce direct normal maps, it has not been run for the remainder of the region outlined here.

Approximately six ground stations will be chosen to develop long-term time series and TMYs.

The SUNY/Albany-DLR high resolution model will be run for each of the three countries.

NREL/CSR	$75K
NREL Time Series	$6K
NREL Cross-model validation and Regional Support	$10k
DLR	$30k
SUNY/Albany	$ 6k
Ministry of Energy (Kenya)	$24k

Ghana

The NREL/CSR model will be run for the entire region of Africa that includes Kenya, Ghana, and Algeria. Although the model has been run for northern Africa to produce direct normal maps, it has not been run for the remainder of the region outlined here.

The SUNY/Albany-DLR high resolution model will be run for each of the three countries.

NREL/CSR (see Kenya)	
NREL Time Series	$6k
NREL Cross-model validation and Regional support	$10k
DLR	$30k
SUNY/Albany	$6k
Ministry of Energy (Ghana)	$23k

Ethiopia

Ethiopia was included in the regional medium-resolution direct normal map that NREL has prepared using the CSR model. However, since that map was prepared, NREL has obtained access to improved data sets. In addition, no maps of global horizontal or diffuse were developed. Thus the CSR model will be re-run for Algeria within the regional SWERA domain defined for Africa.

Approximately nine ground stations will be chosen to develop long-term time series and TMY data sets.

Earlier versions of DLR's direct normal model have been run for Algeria but they do not have the high resolution needed for siting solar thermal power plant. A newer version will be run for SWERA, which will include the global horizontal and diffuse algorithms provided by SUNY/Albany.

NREL/CSR (see Kenya)	
NREL Time Series	$ 9k
NREL Cross-model validation and Regional Support	$10k
DLR	$35k

SUNY/Albany	$ 7k
Ethiopian Energy Development Centre	$24k

GIS and National Planning Tasks

Development of Alternative Energy Investment plans and promotion will be lead by TERI and implemented through national agencies in all pilot countries with further assistance from INPE and UNEP/DTIE. Since the maps will cover more than the participating countries and be available through the UNEP/GRID website, the GIS tools and assistance to further national agencies will be provided through the UNEP/GEF Sustainable Alternatives Network project (before council May 2001).

National agencies	$271k
TERI	$110k
INPE	$ 50k
UNEP/DTIE (to be allocated as investors are identified)	$203k

ANNEX I TERMS OF REFERENCE FOR COLLABORATING AGENCIES

TERMS OF REFERENCE FOR SWERA LEAD NATIONAL COLLABORATING AGENCIES

ACTIVITY COMPONENT 1: SOLAR RESOURCE ASSESSMENT

Activity 1.1 Solar Methodology and Information Review Panel

A solar review committee will be established to review available information and assessment capacity from each participating country. The review committee will include relevant country partner experts, solar experts from SWERA, and independent experts. Existing country data will also serve as validation or comparison data sets and as background reference data.

LEAD NATIONAL COLLABORATING AGENCY will nominate National experts to this committee and participate in the identification of data and quality assessment. This will include a review of the proposed GMS and INSAT satellite data set and resulting map outputs to be provided by DLR.

An output of this review activity will be technical reviews of all data sets and the associated methods. These reviews will define how the SWERA activities will add value to existing solar resource information and will be available to support informed selection and use of existing data in the global archive.

Activity 1.2 Gather Relevant Meteorological Data from National or other Archives

LEAD NATIONAL COLLABORATING AGENCY or the designated country partner will gather relevant in-country data sets to support the solar assessment process. Such data sets include solar validation data and meteorological data used as input to the models (such as surface temperature and relative humidity, aerosol optical depth). Of particular value will be the identification of and access to specialized data sets that are not normally available as part of routine weather station observations. For example, data collected for research purposes, data available through universities or private parties, and data collected by other government agencies such as agricultural offices can be useful to the solar assessments.

An output of this activity will be the compilation of data sets and reports that LEAD NATIONAL COLLABORATING AGENCY and the country partners can use in conjunction with the SWERA team for the solar assessment work. Country partner roles will also include the reprocessing of selected data sets to be used into the solar assessment methodologies and incorporated into the final data archive (TMY, validation data).

Activity 1.3 Develop Solar Resource Maps

LEAD NATIONAL COLLABORATING AGENCY or the designated national representative will monitor the progress of map development and provide technical comments on the output.

Activity 1.4 Generate Time-Series Data

Typical Meteorological Year datasets will be developed from selected ground based three-hourly observations of cloud cover data collected over a period of 20-years or more for up to 100 sites, representing 6-10 sites in each targeted country. LEAD NATIONAL COLLABORATING AGENCY will monitor this activity and participate in the use of ground based measurements and comparisons to model generated TMYs.

Activity 1.5 Relate short-term satellite-derived time series to long-term ground-based time series

Existing tools and software will be configured and made available within the GIS tools of this project to relate time series data from the shorter-term satellite-derived model datasets, to the longer-term surface-derived data sets, so that TMY data can be adjusted to any grid cell available from the satellite data. These tools will be developed by members of the SWERA team and will work with the country partners to assure each country has the ability to use these tools and data sets.

Activity 1.6 Conduct Cross-Model Comparisons and Validation Studies

Cross-model comparisons among the results of the various methodologies identified above will be conducted to establish uncertainty limits for the model results. Validation studies, using existing ground data sets provided by LEAD NATIONAL COLLABORATING AGENCY or country partners, will also be used to validate the various modeling approaches, and establish further information on the uncertainty of the model results. LEAD NATIONAL COLLABORATING AGENCY will provide comment and technical review of the solar assessment with regard to confidence in the information, appropriate use of the various forms of data and opportunities for improvement and expansion of the assessment in The country.

Activity Component 2: Wind Resource Assessment

Activity 2.1 Review of Existing Wind Surveys and Assessment Methodologies

A wind review committee will be established to review available information methods and assessment capacity in the country. LEAD NATIONAL COLLABORATING AGENCY will designate country partner experts, to work with wind experts from SWERA. The purpose of the review is to identify the wind resource, assessment capacity and related information already available to the country or region. This will form a baseline for the project. A selection from the existing country data will serve as validation data sets and as the reference data for interannual, diurnal and seasonal variability. LEAD NATIONAL COLLABORATING AGENCY or the designated country representative(s) will designate the areas of interest for mapping by NREL and additional analysis using a mesoscale model by Risoe.

An output of this review project will be technical reviews of all data sets and methodologies used. These reviews will be available to support informed selection and use of existing data, and to define how the SWERA activities add value to existing information. In an effort to build up analytical and data processing capability in partner countries, models and methodologies used to produce the wind map/atlas will be documented and made available through the SWERA archive.

Activity 2.2 Gather Existing Relevant Wind Data
LEAD NATIONAL COLLABORATING AGENCY or designated country partners will work with the SWERA team to assist in gathering relevant in-country data sets to support the wind assessment process. This includes the identification of existing wind data available from meteorological agencies and other sources. The different types of data to be identified include data collected from surface stations (i.e., ground-based measurements), upper-air stations (i.e., weather-balloon measurements), and marine data where available (i.e., ships, buoys). Data identified by in-country partners will be compared to data that are available from SWERA through its global datasets selected in-country data that are supplementary obtained for use in the assessment.

An output of this activity will be the compilation of data sets and reports that LEAD NATIONAL COLLABORATING AGENCY can use in conjunction with the SWERA team for the wind assessment work. LEAD NATIONAL COLLABORATING AGENCY 's role may also include the reprocessing of data sets (such as supplementary weather balloon data) so that they can be input to the computer wind assessment methodologies.

Activity 2.3 Process Data Sets and Perform Critical Analysis of Data Quality
The SWERA team will collaborate with LEAD NATIONAL COLLABORATING AGENCY or designated country partners on the methods to be used for processing and analysing the various model input data sets. The SWERA team will share processed summaries of data from global data sets (e.g. DATSAV2) with LEAD NATIONAL COLLABORATING AGENCY who will assist with the analysis of the data quality. Qualified regional or national experts will process their in-country data sets, with guidance from the SWERA team to facilitate the use and integration of these data with the models.

The final critical analysis of the data to select the best and most reliable data for developing meteorological inputs to the models will be made by the SWERA team with in country assistance, particularly where qualified experts are available.

Activity 2.4 Adjustment of Surface Observations using WAsP methods
LEAD NATIONAL COLLABORATING AGENCY and designated country partners (at least 5 people) will be trained by Risoe on the use and application of a highly localised method (WAsP) for adjusting ground measurement data and developing time-based information. CrRED and the country partners will apply these methods to selected data for use in verification of computer-generated wind maps and expansion of the assessment information to include variations over time.

Activity 2.6 Prepare Wind Atlas
The preparation of the wind atlas document (non-map, meta-data stored information including interpretation of the wind maps and summaries of the salient wind characteristics) will be the responsibility of LEAD NATIONAL COLLABORATING AGENCY and country partners.

They will provide the data such as the hourly time-series data and with technical support from Risoe and NREL, prepare the summaries, graphical output of the data, and outputs of selected data sets with inter-annual, monthly, and diurnal variations for the meta-data sets in the global archive.

Activitiy 2.7 Conduct Cross-Model Comparisons and Validation Studies

For specific areas identified in 2.1, cross-model comparisons among the results of the various methodologies will be conducted to establish uncertainty limits or confidence levels for the model results. Validation studies, using existing ground data sets obtained through LEAD NATIONAL COLLABORATING AGENCY and country partners, will be used to gain confidence in the modeling approaches, and establish further information on the uncertainty of the model results. LEAD NATIONAL COLLABORATING AGENCY will provide technical input and commentary to the comparison study.

Activity Component 3: Integration with Geographic Information System (GIS)
Activity 3.1 Develop standard GIS datasets
Geospatial Database Development. Geospatial datasets will be developed from the results of the solar and wind resource assessment activities. These datasets will be in a standard format, allowing for easy importation into commercial GIS software packages. These datasets will also be included within the GIS Toolkit and project archive sites for distribution. National Agencies will be responsible for distribution of products to their stakeholder community.

Activity 3.2 Develop GIS Toolkit
The Designated National collaborating partner(s) will provide feedback on the GIS tools and information developed in the project. The emphasis will be on the utility to investors and planners.

Activity 3.3 Needs assessment for in-country partners
The needs of in-country partners will be assessed based on their ability to implement the GIS component of this project. The amount and type of incremental capacity building with the in-country partners will take into account the environment in which current GIS capability resides, the existence and availability of databases, the capability to provide customer support and training, and finally, GIS infrastructure maintenance and sustainability. A regional collaborative agency will provide any of these services should an in-country partner with adequate capacity not be available. The in-country or regional partner will work in close collaboration with the SWERA Team to perform the necessary GIS related activities. Subject to needs and availability, these activities could include data compilation and integration, establishing a local data archive and dissemination facility, accessing databases for inclusion in the project, or training other national energy, wind and solar specialists.

Activity 3.4 Establish global archive
A global archive of solar and wind information with reference data sets and technical reviews supporting informed use will be established. UNEP/GRID facility will design the archive and dissemination activities to be replicated by regional/in-country partners. Additional archival locations and dissemination activities will be established during the project by regional or country collaborators to contain more country specific data. More country specific data sets (ie. electricity grid) will be under the control of LEAD NATIONAL COLLABORATING AGENCY or country agencies, with dissemination activities taking place accordingly.

UNEP/GRID will develop an Internet world-wide-web site. Regional and country centers will distribute products by offering CD-ROMs, Internet distribution, or other means. The regional and national partners will work in close collaboration with the SWERA team to perform the necessary integration, conversion, and dissemination activities.

Activity Component 4: National Application of the SWERA tools and information
Case studies in the utilization of SWERA tools in energy planning will demonstrate the potential for support to planning and development. The advantages of the information and tools leading to better targeted and more effective preinvestment resources, more accurate techno-economical analysis leading to realistic cost-benefit projections, framing specific policies and financial incentives to attract private sector investment, and energy development policies. This activity will enhance existing activities by other agencies where they are operating and the tools further delivered through the UNEP Sustainable Technology Advisory Network.

These products (and data) can be effectively used in national energy planning case studies exercises in the estimation of exploitable wind/solar resource potential under various scenarios, identification of potential regions of interest within the country and matching of resource availability with needs of population centres. The estimation of share of unserved energy demands that could be met by wind/solar energy in energy deficit pockets/regions can also be made. Other relevant analyses depending on available national data for electric grid lines, roads, etc. would also be included. The information can be marketed directly to investors who may not otherwise be reached.

Activity 4.1 Alternative business development scenarios in energy supply
This activity will demonstrate the outcomes of SWERA by developing and presenting solar and wind energy investment opportunities to investors. Marketing and outreach activity will require special efforts to reach investment decision-makers in venture capital companies, independent power producers, and utilities.

To create the business scenarios, information from other sources will need to be assembled. Drawing on existing national activities and GHG inventories, a number of demand growth scenarios would be selected. These will include national development plans. The work will consist of a review of available projections and selection of a few representative scenarios as opposed to a full mitigation analysis study. A nationally oriented technology mix will be identified that is a marketable to potential investors. This will include efficiency factors, nominal line loss characteristics, new load assumptions as required to convert the solar and wind energy resource data into usable potentials. Benchmark technologies will also be used for comparison purposes.

For participating countries, national stakeholders and particularly energy planners will use the energy demand projections, solar and wind resource data, and engineering estimates of potential solar and wind based energy production as input to development of long term solar and wind development scenarios. These alternate business development scenarios can demonstrate the long term strategic potential of renewables, and serve as a basis for estimating GHG emission

reduction potentials. Insights gathered from such exercises can stimulate policy initiatives designed to attract public and private investment in renewable energy projects.

Activity 4.2 Marketing and presentation of the alternative energy development projections to investors

The project will influence investment decisions by promoting alternative scenarios to business-as-usual investment especially in fossil fuel power plant. SWERA and LEAD NATIONAL COLLABORATING AGENCY will present these scenarios directly to banks, financiers and developers to overcome informational barriers in solar and wind projects development for financing.

Expected results are:

- a demonstration of the value of the assessment activities
- an indication of the potential for increased estimates of the global potential for solar and wind energy utilisation.
- investment and policy changes

Activity Component 5. Management and Coordination

Regional meetings will be held during project startup and during the development of the final report on the project. National assessments, regional mapping efforts, and integration/ extrapolation of global significance of the assessment will be developed through this exercise and recommendations made for further improvements in assessment methodologies and coverage. Sharing of information through common training exercises, sharing experiences and validation approaches during the assessment activities will enhance the quality of the assessments. National representatives will be responsible for relaying the information and project outputs back to their respective stakeholder communities.

TERM OF REFERENCE FOR LABSOLAR SOLAR ENERGY RESOURCE ASSESSMENT OF SOUTH AMERICA

Outputs

The following outputs are envisaged for the LABSOLAR solar resource subproject:

- Fine Resolution Maps of daily, monthly and yearly average daily totals of global, diffuse, direct and PAR solar radiations for Brazil. Spatial resolution will be approximately 0.12° x 0.15°. The output data will be based on LABSOLAR/INPE BRASILSR model, which uses as input visible and infrared 3-hourly GOES-8 satellite images, and synthetic one-hourly image.
- Coarse Resolution Maps of monthly and yearly average daily totals of global, diffuse, and direct solar radiation for South America (see Attachment 1). Spatial resolution will be approximately 0.5° x 0.5°. The output data will be based on LABSOLAR/INPE BRASILSR model as above.
- Assist NREL in generating long-term hourly time series of global, diffuse, and direct radiation for a limited selected observation sites in Brazil.
- Distribution of solar radiation incident on tilted surfaces.
- Documentation of all output data sets, including methodology, input data, quality assessment and validation of output data, and statistics of daily, monthly and yearly variability.

Activity 1 Methodologies and Information Review

LABSOLAR will provide the solar review committee established by the SWERA partners with information on the methodology of ground measurements and satellite estimations of solar radiation, validation of the models, and generation of solar maps developed by LABSOLAR/INPE.

Activity 2 Select Relevant Solar Radiation Data

An analysis of the data availability and quality of relevant solar radiation datasets from the South American requesting countries will be done. These data will be used for validation studies of different estimation models, and to generate time-series when possible. Different data sources, such as weather stations, universities, private parties or other government agencies will be contacted in order to obtain a more representative data set. The radiometer calibration facility of the LABSOLAR can be used to verify the quality of the gathered measured data when necessary.

The data from the LABSOLAR ground stations network will be available as a counterpart of the project. This network includes 2 BSRN stations (Manaus – AM and Florianópolis – SC) and 4 another from the CELESC (electricity utility company of Santa Catarina state) / LABSOLAR partnership.

Activity 3 Development of Solar Resource Maps

LABSOLAR will implement in a partnership with INPE new routines and input parameters to set up the solar radiation model BRASIL-SR for South America to calculate the direct, diffuse and PAR (Photosynthetic Active Radiation) radiations. Routines to derive the solar radiation on tilted planes will also be included in this pack. The image processing software will have to be modified to work with the new images and resolution proposed in the project.

A new satellite image archive will be created for South American region. The satellite images will be acquired from INPE in a 3-hourly and synthetic one-hourly basis. A qualification procedure will be implemented in order to obtain the historical satellite image archive for this project. The LABSOLAR/INPE satellite data archive since 1996 for the Brazilian part of South America and since 1998 for whole South America will be provided as counterpart of the project.

Solar radiation maps of global, direct, diffuse, and PAR in horizontal plane will be derived from the satellite images. The maps will be available in monthly and yearly basis, and in a ground resolution of 0.5°x 0.5° for South America. The maps will be also available daily and in a ground resolution of 0.12°x 0.15° for Brazil and requesting countries.

Activity 4 Generation of time series data and relate short-term satellite-derived time series to long-term ground-based time series

The datasets of South America gathered during the project will be used for the generation of Typical Meteorological Years for selected sites in South American requesting countries. This subtask will be achieved in close collaboration with NREL and assisted by INPE to build the capacity to perform the calculations of the TMY derived from surface data and from satellite data. The time series data from the shorter-term satellite-derived data sets will be related to the longer-term surface-derived data sets provided by NREL, so that it will be possible to obtain TMY data for any grid cell.

Activity 5 Validation Studies

The data sets described in Activity 2 will be used to validate and establish the expected uncertainty of the BRASIL-SR satellite model.

Generate the necessary BRASIL-SR model data to assist INPE-National in the cross-model comparison among LABSOLAR/INPE BRASIL-SR, NREL CSR, SUNY's GHI, and DLR's DNI models.

Activity 6 Develop standard GIS datasets

LABSOLAR will work in close collaboration with the regional agency so that the derived radiation maps will be in a standard format to allow the integration with commercial GIS software packages. Additional information as identification, quality assessment, organizations, spatial and temporal reference and any other additional attribute will be also included.

Activity 7 Utilization of the SWERA tools and information in energy planning

The model results of the solar radiation resource derived by LABSOLAR will be gathered with additional GIS information provided by INPE and CEPEL/ELETROBRAS for Brazil, and by other South American requesting countries to generate useful information for energy planning and development. Different scenarios of the solar resource utilization will be simulated and specific policies and financial incentives to attract the private sector investment could be established.

Activity 8 Documentation

Final documentation of all model results, validation, and cross-comparison studies, will be developed and posted with the final archive. The documentation shall include:

- Theoretical background of the BRASILSR model;
- Description of model input meteorological data sets;
- Description of validation data sets from the selected validation sites in Brazil;
- Resulting hourly time series and TMY datasets in collaboration with NREL.
- Description of quality assessment including the applied methodology, reference data and the results of quality assessment for South America
- Solar radiation maps of global, direct, and diffuse in tilted planes with data quality assessment for PV, water heating, air-conditioning, process heat, and building simulation systems.
- Statistical maps of radiation variability will be provided in the same resolution as the radiation maps.

TERMS OF REFERENCE FOR NREL MEDIUM RESOLUTION SOLAR RESOURCE ASSESSMENT

Outputs

The following outputs are envisaged for the NREL solar resource subproject:

- Maps and GIS data sets of monthly and yearly average daily totals of global, diffuse, and direct normal solar radiation over four major regions around the world, outlined in Attachment 1: Central America and the Caribbean, South America, Africa, and South and East Asia. Spatial resolution will be approximately 40-km. Accuracy of the monthly and average values will be approximately 10%. The output data will be based on NREL's Climatological Solar Radiation

model which uses, as input, a world-wide dataset of 7-year histograms of monthly average cloud cover at 40-km resolution.

- Long-term hourly time series of Global, Diffuse, and Direct Radiation for 6-10 ground weather observation station locations in each endorsing country. These data will be statistically analyzed and converted into Typical Meteorological Year datasets so that they can be input directly into technology performance models, and be used for economic assessments. The stations will be selected during the project in collaboration with the country partners.
- Documentation of all output data sets, including methodology, input data, and quality assessment and validation of output data.
- In-country Training Materials on the development and use of solar resource data sets and solar measurement techniques.
- Coordination of solar activities and products among all project participants.

Activity 1: Gather and Develop Relevant Meteorological Data

Working with country partners, NREL will gather relevant in-country data sets to support the solar assessment process. Such data sets include solar validation data and meteorological data used as input to the models (such as surface temperature and relative humidity, aerosol optical depth). Of particular value will be the identification of and access to specialized data sets that are not normally available as part of routine weather station observations. For example, data collected for research purposes, data available through universities or private parties, and data collected by other government agencies such as agricultural offices can be useful to the solar assessments.

An output of this activity will be the compilation of data sets and reports that the country partners can use in conjunction with the SWERA team for the solar assessment work. Country partner roles will also include the reprocessing of selected data sets to be used into the solar assessment methodologies and incorporated into the final data archive (TMY, validation data).

Activity 2: Produce Medium Resolution Climatological Solar Datasets

Medium resolution (approx. 40 km x 40 km) climatological solar resource data sets, comprising monthly average daily total global horizontal, direct normal, and diffuse solar resource elements, will be developed for four major regions of the world: Mexico/Central America/Caribbean, South America, Africa, and South and southeast Asia (including China). Tools to calculate the resource for various collector orientations will be included in these databases.

Activity 3: Produce Time-Series Data

Using the worldwide DATSAV2 data archive at NREL, long-term time series for approximately 6-10 stations per country will be developed. The archive includes 3- or 6-hourly cloud cover observations, as well as other meteorological observations, obtained from national weather service sites around the world. The archive contains approximately 20,000 stations, and typically the period of record for each station is at least 20 years. *Someone might ask for it so if not to be made available, suggest we don't mention a distributable format…*NREL's Meteorological-Statistical (METSTAT) model will be used to convert these data sets to hourly values of global, diffuse, and direct normal solar radiation. From this output, Typical

Meteorological Year datasets will be developed. This activity will be coordinated with the time series data being generated by SUNY/Albany and DLR, and incorporated into the GIS.

Activity 4: Conduct Validation and Quality Assessment Studies

The global and direct data sets will be compared with existing ground data made available either from the national partners, or through international archives. Results of these validation studies will be included in the final documentation. Using NREL's SERI/QC data quality assessment software, the data used for validation purposes will be checked for consistency, and the data will be flagged according to the results. The flags of validation data as well as quality notes on the modeled data sets will be included in the final data archives. Assistance to national partners in quality control procedures and validation against selected ground measurements?

Activity 5: Conduct Cross-Model Intercomparisons

NREL will participate in cross-model comparisons of the various methodologies being used in SWERA. These studies will be conducted to establish uncertainty limits for the model results. For example, a cross-model comparison of NREL's CSR model and INPE-LABSOLAR's BRASIL-SR satellite-derived solar model will be conducted in climatologically specific regions of Brazil, so that the results of the two modeling approaches can be used to define the uncertainty limits of their outputs. These studies will also establish the relative performance of the BRASIL-SR region-specific model to the global dataset developed from the CSR model. Results of these studies will be posted with the final SWERA data archive. Much of the support for these cross-model comparisons will come from in-kind parallel co-financing.

Activity 6: Documentation, Coordination, and in-Country Training

Final documentation of all model results (40-km datasets, TMY datasets), and validation and intercomparison studies, will be developed and posted with the final archive. The documentation shall include:

- Theoretical background of the METSTAT and CSR models
- Description of input data sets including the cloud cover data sets, related meteorological data such as precipitable water and aerosol optical depth data;
- Description of validation data sets either provided by the country partners, or made available through international data archives
- Resulting maps and GIS data sets
- Resulting hourly time series and TMY datasets
- Description of quality assessment including the applied methodology, reference data and the results of quality assessment for each regional analysis
- Training materials for use with in-country resource assessment training activities.

In addition, NREL will provide technical assistance to the UNEP/DTIE SWERA Program Manager and to the SWERA technical team in the overall coordination of all solar-related activities and products.

TERM OF REFERENCE FOR INPE-REGIONAL – IMPLEMENTATION OF THE LATIN AMERICA REGIONAL AGENCY

Output

- The main contribution of INPE to the SWERA project is linked to its Activity Component 5 (Management and Coordination). UNEP/DTIE will coordinate the SWERA project with

assistance from INPE as a Regional Implementation Agency for the Latin America sub-region. INPE will provide services to countries in their regions as needed and, where appropriate, coordinate the activities among national partners. The goal is to develop the technical capability to ensure that SWERA products are effectively and efficiently utilized to achieve accelerated and continued deployment of solar and wind energy systems

Activity 1 Coordination between SWERA team and national partners of the region

INPE-Regional agency will assist UNEP in the coordination and hosting of technical regional meetings and training of participating countries. Regional meetings will be held during project start-up and during the development of the final report on the project. National assessments, regional mapping efforts, and integration / extrapolation of global significance of the assessment will be developed through this exercise. Recommendations will be made for further improvements in assessment methodologies and coverage.
Follow-up visits to regional participating countries and national partners will be made in order to verify the outcomes of project activities and schedules. The regional agency will provide also the information link between requesting countries and the SWERA team in order to follow up these activities locally.

Activity 2 Assistance to national partners in data quality assessment & refinement

In this activity, INPE-Regional will assist national collaborating agencies in gathering, processing and performing critical analysis of relevant in-country data sets to support the solar and wind assessment process. This includes the identification and selection of existing data available from meteorological agencies and other sources.
Qualified national experts will process their in-country data sets, with guidance from the SWERA team and with the assistance from INPE to facilitate the use and integration of these data with the models.
INPE will work in association with CBEE in providing technical support and training to participating country partners on the use and application of a highly localised method (WAsP) for adjusting ground measurement data and developing time-based information.

Activity 3 Work with SWERA Technical Support Agencies (NREL, SUNY, DLR, & Risø) in the development of maps and receive incremental capacity building in assessment techniques

Generate solar time-series data in collaboration with NREL; relate short-term satellite-derived solar time series to long-term ground-based time series; organize cross-model comparisons and validation studies for wind and solar radiation; coordinate the regional review of existing solar and wind surveys and assessment methodologies in collaboration with LABSOLAR, CBEE, CEPEL, INMET, INPE, and participating countries.

Activity 4 Assist SWERA team in the development of geospatial datasets from the results of the solar and wind resource assessment.

INPE-Regional will identify in-country partners based on their ability to implement the GIS component of this project in order to provide the integration of regional solar and wind resource assessment products into the Geographic Information System (GIS) format. Should an in-country partner with adequate capacity not be available, INPE-Regional will perform this service. INPE-Regional will work in close collaboration with the SWERA team to perform the necessary GIS related activities. Subject to needs and availability, these activities could include data compilation and integration, establishing a local data archive and dissemination facility, accessing databases for inclusion in the project, or training other national energy, wind and solar specialists.

Activity 5 Dissemination of SWERA products and outreach to investors

INPE-Regional will assist UNEP and the SWERA team in the establishment of global archives of solar and wind information with reference data sets and technical reviews. One of these global archives will be implemented through national UNEP/GRID facilities that will design the archive and dissemination activities to be replicated by regional/in-country partners. The standard, public domain products generated by the SWERA project will be freely accessible by international investors, agencies, and developers.
INPE-Regional will assist UNEP/GRID in the development of an Internet world-wide-web site. This site will house the archive, act as a clearinghouse for searches, and disseminate products across the Internet. All inquiries and special data or service requests will be automatically directed to the SWERA team websites for processing. INPE and the Latin American national collaborating country centres will distribute products by offering CD-ROMs, Internet distribution, or other means. INPE and national partners will work in close collaboration with the SWERA team to perform the necessary integration, conversion, and dissemination activities.

Activity 6 Provide capacity building to national organizations in use of resource maps and SWERA tools for energy planning

INPE-Regional will work in conjunction with Brazilian collaborating centres such as the LABSOLAR, CBEE and CEPEL to put forward case studies in the utilization of SWERA tools in energy planning to demonstrate the potential for support to planning and development.
INPE-Regional will assist UNEP in partnership with Brazilian and regional collaborating agencies in marketing and presentation of the alternative energy development projections to investors. The various dissemination formats will include, limited hardcopy maps and reports, web-based access to information, CDROM information only, and CDROM information with user-friendly tools. The core solar and wind information will be housed in the global archive, however, the national collaborating agencies, with backup from INPE and TERI will be able to customise and modify the auxiliary data (electric grid lines etc) and provide customised services and products to regional clients. Confidentiality of auxiliary data will be negotiated in respect of national requirements and proprietary rights.

TERMS OF REFERENCE FOR BRAZILIAN WIND ENERGY CENTRE - CBEE

Outputs
The following outputs are envisaged for the CBEE subproject:

- Membership of wind assessment methodology review
- Compilation of wind data sets to be used in the wind assessment methodologies
- WAsP training and follow up for Latin American country partners
- Wind maps for Brazil. MM5 model will be used to generate wind maps for a region in Brazil (to be determined) with 20km resolution. WasP model will be used to refine the MM5 outputs and generate high-resolution wind maps for selected areas.
- Wind Atlas document including theoretical principles, methodology, data description and results.
- Case studies and demonstration on using SWERA products for identification of potential areas of interest, support to planning and development of wind projects, more accurate techno-economical analysis and national energy planning.

Activity 1: Membership of Assessment Methodologies Review
CBEE will review available information and wind assessment methods in Brazil in order to identify good quality data sets and information on wind resource and wind climatology. The review will indicate areas of interest for mesoscale model simulations (KAMM and MM5) and available wind data for models' validation.

Activity 2: Gather Existing Relevant Wind Data in Brazil
CBEE will identify all wind data available from wind assessment programs, meteorological stations and other sources in a specific area of Brazil (to be determined). The relevant data sets identified in this activity will be compared to the global (e.g. Reanalysis Project) and regional data sets in order to validate/correct the inputs of the wind assessment methodologies.

Activity 3: Preprocess Data and Analysis of Data Quality
In this activity CBEE will work in collaboration with NREL and Risø for processing and analyzing the data sets in order to facilitate the use and integration with NREL's wind assessment method and KAMM mesoscale model.

Activity 4: WAsP Training and Application
CBEE will host a WAsP course in Recife-PE(Brazil) with Risø trainers and attendees from Latin American country partners. The course will include training in the theory behind wind resource modeling and in the use of the computer program WAsP. CBEE will assist Risø trainers, provide training facilities (computers?) and provide translations if necessary.
The course participants will apply WAsP to evaluate the wind resources in their regions and/or verify existing wind maps. As a follow up to the training CBEE will provide technical support to all country partners verifying the calculations carried out by the countries and assisting them in performing validation of the computer-generated wind maps.

Activity 5: MM5 Modelling
The SWERA team and CBEE will define a region (around 200,000 km^2) for the application of MM5 mesoscale model in Brazil. NREL will generate a high-resolution map for the same region

and RISØ will run KAMM in high-resolution mode for 2 selected (smaller) areas within the region.
CBEE will run MM5 for a region in Brazil and generate a wind map with 20km resolution. High-resolution maps (1km) will be developed for some selected areas (including the areas selected for KAMM runs) using the combination of MM5 and the microscale model WAsP.

Activity 6: Conduct Cross-Model Comparisons and Validation Studies
Cross-model comparisons among the results of the various methodologies will be conducted to establish uncertainty limits or confidence levels for the model results. CBEE will perform validation studies using existing reliable wind data (from anemometer towers) to gain confidence in the modeling approaches, and establish further information on the uncertainty of the model results.
CBEE will provide technical input and commentary to the comparison study among the models used in Brazil (WRAMS/NREL, KAMM/RISØ, and MM5/CBEE). Other models can be included in the comparison study if their results are available.

Activity 7: Wind Atlas Preparation
CBEE will prepare the Wind Atlas document including theoretical principles, methodology, data description and results for the region defined in activity 5.
The Wind Atlas document will contain:

- Theoretical principles of the wind climatology and resource assessment methodologies. Description of atmospheric models and methods for wind mapping.
- Description of the wind atlas methodology.
- Description of input meteorological data sets.
- Wind maps and wind resource information including summaries, graphical output of the data, interpretation of the wind maps, outputs of selected data sets with inter-annual, monthly and diurnal variations, Weibull distributions and other important characteristics of the regional wind climatology.
- Information on using the Atlas for site-specific performance modeling and economic assessment of wind projects.
- Description of quality assessment including the applied methodology, reference data and the results of several models.

Activity 8: Develop Standard GIS Datasets
CBEE will collaborate with SWERA team to generate wind resource assessment information for Brazil in a standard format allowing for easy importation into commercial GIS software packages and integration with SWERA products. The information will include spatial representation of the wind resource and the associated attributes.

Activity 9: Application of the SWERA Tools in Brazil
CBEE will collaborate with the regional agency on preparing case studies and demonstration on use of wind resource maps (i.e. SWERA products) and marketing in Latin America. The case studies will improve dissemination of the SWERA products through demonstration of using these tools in identification of potential regions of interest, support to planning and development of wind projects, more accurate techno-economical analysis and national energy planning.

TERMS OF REFERENCE FOR RISØ NATIONAL LABORATORY COLLABORATING AGENCIES

Outputs

The following outputs are envisaged for the Risø subproject:

- Membership of wind mapping methodology review panel
- WAsP training for adjustment of surface data
- Run KAMM model for selected areas

Not easily quantified but an output of the project as well is the improved knowledge, skills, and confidence on the part of project partners, which will enable them to identify situations in which micro-siting of wind farms using WAsP can contribute to national energy needs and to remove barriers for investment decisions;

Activity 1: Membership of review panel

In view of the wide range of capability found among the participating countries of the project, it is expected that a wide range of existing information and assessment capacity on wind energy resources will also be available. In this task, a wind review committee will be established to review available information methods and assessment capacity in each country. The review will include relevant country partner experts, wind experts from SWERA, and independent experts. The purpose of the review is to identify the wind resource, assessment capacity and related information already available to the country or region. This will form a baseline for the project. A selection from the existing country data will serve as validation data sets and as the reference data for interannual, diurnal and seasonal variability. Areas of interest for additional analysis using a meso-scale model will also be identified.

Output: technical reviews of all data sets and methodologies used. These reviews will be available to support informed selection and use of existing data, and to define how the SWERA activities add value to existing information. In an effort to build up analytical and data processing capability in partner countries, models and methodologies used to produce the wind map/atlas will be documented and made available through the SWERA archive

Activity 2: WAsP training

2.1 For each region Risø will carry out a 4 day extended WAsP course. The course will include training in the theory behind resource modeling and in the program itself. A case study will be carried out and the last day will be used in training the participants in doing the evaluation task.

Output: "WAsP Experts" capable of carrying out the validation of the NREL maps using in-country meteorological data.

2.2 Once the validation work has been carried out in the countries, the results with all accompanying data are sent to Risø for quality assurance. Risø will access the total quality of the calculations including meteorological data, maps and the wasp calculations themselves.

Output: quality assured country calculations

Activity 3: KAMM runs for selected areas

3.1 work with NREL to find areas (2) for KAMM modeling in each country. For each of the countries a number (2) of areas where the flow is complex in some way will be identified for KAMM calculations.
Output: 2 areas for each country where KAMM will be run.

3.2 carry out KAMM modeling for these areas For each of the selected areas, KAMM will be run in a high-resolution mode (5km x 5km).
Output: WAsP compatible wind atlas files (.LIB-files) will be produced for each grid point.

TERMS OF REFERENCE FOR NREL WIND RESOURCE ASSESSMENT

Outputs

The following outputs are envisaged for the NREL wind resource assessment subproject:

- Maps and GIS data sets: High-resolution (1-km) annual average wind resource maps and GIS data sets for specific countries or areas of Central America and the Caribbean, South America, Africa, and South and East Asia, as outlined in Attachment 1. Accuracy of the resource values is expected to be approximately 10% in wind speed and 20% in wind power at more than 80% of locations. The output data will be based on NREL's Wind Resource Assessment and Mapping System (WRAMS) which uses, as input, analyses of existing surface and upper-air meteorological data sets covering many years of record. Other outputs will include elevation maps at the same spatial resolution (1-km) and scale of the wind resource maps, and maps showing the locations where measurement data were available for analysis.
- Documentation of data sets and information available for analysis, based on a review of NREL's global data sets and data identified by country/regional partners. A list will be prepared of the available surface and upper-air meteorological data (including location coordinates, time period of data, etc.) for areas within or close proximity to areas covered by the assessment.
- Processed summaries of data from NREL's global data sets and data provided by country/regional partners. These summaries will be provided (in graphic and/or tabular form) to country partners for use in analyzing the data and for describing the salient wind characteristics (inter-annual, seasonal/monthly, diurnal, directional, etc.) as part of the atlas preparation.
- Review of wind atlas documents developed by country/regional partners
- Documentation of methodology and assessment techniques.

Activity 1: Gather Existing Relevant Wind Data

NREL will review the available data in its global data sets for use in each country or regional assessment. In collaboration with the SWERA team and designated country partners, we will review relevant in-country data sets identified by the country partners. This includes the identification of wind data available from meteorological agencies and other sources. The different types of data to be identified include data collected from surface stations (i.e., ground-based measurements), upper-air stations (i.e., weather-balloon stations), and marine data where available (i.e., ships, buoys). Data identified by in-country partners will be compared to data that are available from NREL through its global data sets. We will assist the country partners in selecting data sets that should be obtained to supplement NREL's data for use in the assessment.

An output of this activity will be the compilation of data sets and reports that the country partners can use in conjunction with the SWERA team for the wind assessment work. Country partner roles may also include the reprocessing of selected data sets to make them more useful in the wind assessment methodologies.

Activity 2: Process Data Sets and Perform Critical Analysis of Data Quality

NREL will collaborate with designated country and regional partners on the methods to be used for processing and analyzing the various data sets. NREL will share processed summaries of data from global data sets (e.g., DATSAV2) with country and regional partners who will assist with the analysis of the data quality. Qualified regional or national experts will process their in-country data sets, with guidance from NREL to facilitate the use and integration of these data by SWERA.

The final critical analysis of the data to select the best and most reliable data for use in WRAMS will be made by NREL.

Activity 3: Generate High-Resolution Wind Maps

For the countries/regions identified in Attachment 1, WRAMS will be used to generate high-resolution (1-km) annual average wind resource maps. Other outputs will include elevation maps at the same spatial resolution (1-km) and scale of the wind resource maps, and maps showing the locations where measurement data were available for analysis.

The final maps generated by NREL will be provided to designated country and regional partners for their use in preparation of the country/regional wind energy atlases.

Activity 4: Review Wind Atlas Preparatio*n*

The preparation of the wind atlas document (non-map, meta-data stored information including interpretation of the wind maps and summaries) will be responsibility of country/regional partners. NREL will provide technical support in the atlas preparation through collaboration with the country/regional partners during the atlas preparation. NREL will review the draft atlas products and provide recommendations for the final atlas document.

Activity 5: Conduct Validation and Quality Assessment Studies

NREL will collaborate with country and regional partners to conduct validation studies of the resource estimates for specific areas where high-quality ground measurement data are available. This validation exercise is necessary to establish uncertainty limits or confidence levels for the model results. Existing validation of WRAMS results in several different regions indicate that the accuracy of the resource values is expected to be approximately 10% in wind speed and 20% in wind power at more than 80% of locations.

Activity 6: Documentation, Coordination, and Training

Final documentation of data sets, methodology, and assessment techniques will be prepared. The documentation will include:

- Description of WRAMS and assessment techniques
- Description of available data sets (surface, upper-air, marine, etc.) and other information (reports, previous studies, etc.) from NREL and country partners for use in the assessment
- Description of data processed and summaries generated and provided to country/regional partners for analysis and use in wind atlas preparation
- Resulting maps and GIS data sets generated and provided to country/regional partners for use in wind atlas preparation
- Review of wind atlas document developed by country/regional partners
- Summary of validation and quality assessment activities in collaboration with country/regional partners
- Training materials for use with in-country resource assessment training activities.

In addition, NREL will provide technical assistance to the UNEP/DTIE SWERA Program Manager and to the SWERA technical team in the overall coordination of all wind-related activities and products.

TERMS OF REFERENCE FOR UNEP GRID SIOUX FALLS

Outputs

The following outputs are envisaged for the UNEP GRID Sioux Falls subproject:

- WWW site for visualization and dissemination of standard products
- Archive site for all documented contributed products.
- SWERA Global Spatial Data Infrastructure (GSDI) Clearinghouse

Activity 1: Assist in design of standard data products and tools

1.1: Assist contributing agencies in the definition of standard products and standard formats
1.2: Provide training in the creation of ISO compliant metadata
1.3: Assist in the definition of the GIS tools

1.1 Meet with data providers to ensure that a common data structure and documentation are defined to ensure ease of use by clients.

1.2 A trainer and course materials will be available to conduct a training course in the creation of ISO compliant metadata for the data providers. If appropriate, the course can also include training in the implementation and maintenance of an ISO compliant GSDI clearinghouse. Identification of the attendees will follow from establishment of national and regional partners. Costs for attending the course, facilities (unless held at UNEP GRID SF), hardware and software would be the responsibilities of the national and regional centres.

1.3 Coordinate with GIS tool team, as requested, to support the creation of tools that function with standard products, and are amenable for use in Activity 3.3

Activity 2: Define and implement data archive and dissemination system

2.1 All standard products will be archived and backups of the archive will be maintained on archival quality media.

2.2 A data dissemination mechanism will be built into the www site. All data will be available online at no cost. Detailed documentation of the data and its metadata will be stored and be viewable online.

2.3 The archive will function as "deep" archive for contributed data sets. To be suitable for archive, documentation and ISO compliant metadata must be provided with the data. These data will not be downloadable from the central clearinghouse. These data will be available from the contributing agency, as they see fit. Availability may include restrictions on redistribution and fees. The deep archive will serve the dual purpose of a backup to the national and regional centres and as a long-term backup for SWERA funded data sets. Every effort must be made to maintain data integrity and concurrency between the active archives held by the national and regional centres and the deep archive.

2.4 A SWERA GSDI clearinghouse will be implemented. All metadata will be stored in the clearinghouse and will be searchable through the ISO compliant GSDI clearinghouse system.

Activity 3: SWERA WWW site

3.1 Define and implement centralized SWERA www site to organize and publicise final documentation and data to clients. WWW site will be SWERA's collective door to the world. The www site should organise and display the data and activities of the partners in such a way that is pleasing and provides full credit and visibility to all partners.

3.2 A structured data and document dissemination system should be fully designed and implemented into the SWERA www system.

3.3 Produce web-enable versions of the GIS tools, as appropriate. Many of the GIS tools require quick and flexible access to data that cannot be provided via the Internet. A subset of the functionality should be amenable to conversion to the Internet in such a way that it will provide limited tool for visualizing and understanding the data and their applications.

Activity 4: Assist in the establishment of regional and national www, dissemination and archive sites

4.1: Provide training and assistance in the migration of archive and www structure to national and regional centres.

4.2: Implement a SWERA-specific GSDI Clearinghouse Gateway.

4.1 If regional or national centres have a well-defined requirement to archive and disseminate data consisting of the standard data products and other data products unique to their region or nation, then a trainer will be available to help in the transfer of the standard archive and dissemination structure. This could include an implementation of a GSDI clearinghouse node. Modifications to the structure to suit local requirements will be the responsibility of the regional or national centre.

4.2 A SWERA-specific GSDI Clearinghouse Gateway will be implemented. This Gateway would provide an organizational structure to help clients find solar and wind related resources created during the course of the project. The GSDI clearinghouse system is amorphous and contains hundreds of clearinghouses handling spatial data for all applications. A SWERA-specific GSDI Gateway would act as a moderator or filter to allow ready access to those sites that are most relevant to SWERA activities. The nodes in the Gateway would not need to be limited to SWERA clearinghouse nodes. The Gateway could also provide access to other clearinghouses created for other Solar and Wind projects and to clearinghouses that contain supporting data. Data providers for other projects, particularly those funded through GEF and our partners, could be invited to any training given through the SWERA project. The task, as scoped, is designed to ensure that Solar and Wind data are known and available to project participants.

TERMS OF REFERENCE FOR SUNY HIGH RESOLUTION SOLAR RESOURCE ASSESSMENT

Outputs

The following outputs are envisaged for the SUNY solar resource subproject:

- High Resolution Maps of monthly and yearly average daily totals of global, diffuse, and direct normal solar irradiation for selected countries in Central America and the Caribbean. Spatial resolution will be approximately 10-km. Accuracy of the monthly and average values will be approximately 10%. The output data will be based on SUNY and DLR shortwave satellite-to-irradiance conversion models, using as input, a data set consisting of four years of GOES East and GOES West images covering the northern hemisphere. The maps will be provided to NREL for incorporation into the GIS interface.
- High Resolution Time Series Generation Algorithm: For the selected Caribbean and Central American countries, an algorithm capable of generating high resolution hourly time series from the monthly maps and the selected ground time series will be produced. This algorithm will be implemented by NREL for incorporation in the GIS interface.
- Documentation of all output data sets, including methodology, input data, and quality assessment and validation of output data.

Activity 1: Coordinate high-resolution satellite modeling with DLR
High-resolution irradiances will be generated using SUNY's Global Horizontal Irradiation model and DLR's Direct Normal Irradiation model. The objectives of this activity is to provide SUNY's GHI modeling instructions to DLR for deployment with Meteosat input, and to incorporate DLR's DN I modeling procedure to work with our GOES satellite data.

Activity 2: Conduct Validation and Quality Assessment Studies
The SUNY and DLR algorithms will be tested against high accuracy ground truth data from climatic environments representative of the Caribbean and Central American regions of relevance to the programme. Validation benchmarks will include short-term dispersion accuracy (Root Mean Square Errors) long-term seasonal accuracy (Mean Bias Errors) and frequency distribution accuracy (Skewness and Kurtosis).

Activity 3: Conduct Cross-Model cross-Satellite platform Intercomparisons
In order to insure the coherence and the consistency of high-resolution solar resource information generated throughout the world, satellite models and satellite platforms will be intercompared through a common ground truth location in northeastern Brazil. INPE, DLR and SUNY algorithms will be intercompared using input data from both METEOSAT and GOES satellites.

Activity 4: Produce High Resolution Maps
High resolution (approx. 10 km x 10 km) climatological solar resource data sets, comprising monthly average daily total global horizontal, direct normal, and diffuse solar resource elements, will be developed for the Central America and Caribbean countries participating to the Programme. Maps will be made available to NREL for incorporation in their GIS interface.

Activity 5: Produce and test Time series generation algorithm
An algorithm capable of generating localized hourly data time series based upon: (1) monthly averaged high-resolution maps and (2) time series at some local reference location will be developed for incorporation in the NREL GIS interface.

Activity 6: Documentation, and dissemination
Final documentation of all models and data sets, and validation and intercomparison studies, will be developed and posted with the final archive. The documentation shall include:

- Theoretical background of all satellite-to-irradiance algorithms and time series generation algorithm.
- Description of input data sets including SUNY's GOES East and GOES West archives, and related meteorological data used by the models, including gridded turbidity.
- Description of validation data sets including high accuracy irradiances and NE Brazil common ground truth data.

Activities and results of this project will be included in publications and presented at conference and meetings. Meetings, targeted for presentation of research and products to participating countries, will be determined in coordination with NREL and other members of the SWERA team.

TERMS OF REFERENCE FOR TATA ENERGY RESEARCH INSTITUTE

Subject to confirmation during the detailed appraisal phase for each country, the following activities will be performed by TERI. These activities form the basis of the project budget estimate and are considered a necessary components to achieving the project goals.

ACTIVITY COMPONENT 1: SOLAR RESOURCE ASSESSMENT

Activity 1.1 Solar Methodology and Information Review Panel
Participate in the review panel. Assist the regional partners in identifying data.

Activity 1.2 Gather Relevant Meteorological Data from National or other Archives
Solar radiation measurement data for locations in India that are near to the borders of Bangladesh, Nepal and Sri Lanka will be acquired by TERI in order to validate the regional map.

Activity 1.3 Develop Solar Resource Maps
Access the INSAT data and obtain images as necessary for the regional hi-resolution solar map. *Based on technology transferred from DLR, collaborate in the production of a High resolution* (approx. 0.05^{o} to 0.15^{o}, 1-3 hourly) site/time specific solar resource datasets derived from geostationary satellite data INSAT and METEOSAT5 including targeted countries and regions in each of the four areas defined above. Since INSAT has higher spatial resolution and METEOSAT has higher time resolution the combination will give the best product.

Activity 1.4 Generate Time-Series Data

Typical Meteorological Year data-sets will be developed from selected ground based three-hourly observations of cloud cover data collected over a period of 20-years or more for up to 100 sites, representing 6-10 sites in each targeted country. SWERA will work with the regional collaborators and the country partners to build the capacity for the country agencies to perform these calculations themselves.

Activity 1.5 Relate short-term satellite-derived time series to long-term ground-based time series

Activity 1.6 Conduct Cross-Model Comparisons and Validation Studies
TERI will participate in Cross-model comparisons among the results of the various methodologies identified above will be conducted to establish uncertainty limits for the model results. Validation studies, using existing ground data sets obtained from the country partners, will also be used to validate the various modeling approaches, and establish further information on the uncertainty of the model results. These studies will be enhanced by co-financing from the sponsoring organizations of the participating agencies.

Expected Results: Solar Resource Assessment
TERI will have the capacity to act as a regional centre for ongoing provision of:

- access to enhanced solar resource maps and expanded databases including national validation results and expanded time series information.
- the capacity to use the data in an effective manner to facilitate solar technology investment.
- The capacity to generate high resolution solar maps and time series.

· improved ability to undertake measurement programs for further validation data as well as site-specific pre-feasibility studies

Activity Component 2: Wind Resource Assessment

Activity 2.1 Review of Existing Wind Surveys and Assessment Methodologies

A wind review committee will be established to review available information methods and assessment capacity in each country. The review will include relevant country partner experts, wind experts from SWERA, and independent experts. TERI

Activity 2.2 Gather Existing Relevant Wind Data

Gather relevant data for India weather stations near to the participating countries for validation purposes.

An output of this activity will be the compilation of data sets and reports that the country partners can use in conjunction with the SWERA team for the wind assessment work. Country partner roles may also include the reprocessing of data sets (such as supplementary weather balloon data) so that they can be input to the computer wind assessment methodologies.

Activity 2.3 Process Data Sets and Perform Critical Analysis of Data Quality

The SWERA team will collaborate with the country partners on the methods to be used for processing and analysing the various model input data sets. The SWERA team will share processed summaries of data from global data sets (e.g. DATSAV2) with country partners who will assist with the analysis of the data quality. Qualified regional or national experts will process their in-country data sets, with guidance from the SWERA team to facilitate the use and integration of these data with the models.

The final critical analysis of the data to select the best and most reliable data for developing meteorological inputs to the models will be made by the SWERA team with in country assistance, particularly where qualified experts are available.

Activity 2.4 Adjustment of Surface Observations using WAsP methods

Country partners will be trained by Risoe on the use and application of a highly localised method (WAsP) for adjusting ground measurement data and developing time-based information. The technical assistance will be through TERI.

Activitiy 2.7 Conduct Cross-Model Comparisons and Validation Studies

Validation studies, using existing ground data sets obtained for stations near the participating country partners, will also be used to gain confidence in the modeling approaches, and establish further information on the uncertainty of the model results.

Activity Component 3: Integration with Geographic Information System (GIS)

A Geographic Information System (GIS) is the combination of hardware, software, data, and expertise used to create, modify, evaluate and analyze spatial or geographically referenced information in digital format. GIS data are comprised of two components: spatial features and attributes. The spatial features are elements that can be shown on a map. They include roads, rivers, population density, electric transmission corridors, meteorological stations, and the wind or solar resource distribution. The attributes are the associated information such as land ownership and use (designations such as forest, agriculture, park, etc), temperature, wind speed

and solar radiation values. The combination of both a computerized map and a database within the same system facilitates planning and decision making.

This project will contribute to removing information barriers by integrating the solar and wind resource assessment products into a GIS format. Additionally, the SWERA project will provide an easy-to-use GIS Toolkit that supplements these data products, and is targeted specifically to organizations and individuals that lack GIS capability. Despite the growing presence of GIS throughout the world, it is often not used to facilitate renewable energy project deployment. It is noted that the full set of relevant information will include data sets already available from other agencies such as USGS, NASA, and GRID centres. Unless the information has been modified or adjusted, the most effective means of providing access is expected to be through pointers or web site links to the original source.

Activity 3.3 Needs assessment for in-country partners

The needs of in-country partners will be assessed based on their ability to implement the GIS component of this project. The amount and type of incremental capacity building with the in-country partners will take into account the environment in which current GIS capability resides, the existence and availability of databases, the capability to provide customer support and training, and finally, GIS infrastructure maintenance and sustainability. TERI will provide any of these services should an in-country partner with adequate capacity not be available. The in-country or regional partner will work in close collaboration with the SWERA Team to perform the necessary GIS related activities. Subject to needs and availability, these activities could include data compilation and integration, establishing a local data archive and dissemination facility, accessing databases for inclusion in the project, or training other national energy, wind and solar specialists. UNEP will closely monitor and approve the selection of assessment activities in order to ensure targeting of best opportunities for global benefits and avoiding duplication with national or other agency actifities.

Activity Component 4: Coordination of the National Application of the SWERA tools and information

TERI will coordinate the work under this activity.

Preparation of templates for analysis, standardised use of of economic/ engineering models for analysis.

Collation of all the studies into a final report covering all the countries as well as any global or regional conclusions that can be drawn as to the impact and effectiveness of the mapping work and its effect on investment.

Case studies in the utilization of SWERA tools in energy planning will demonstrate the potential for support to planning and development. The advantages of the information and tools leading to better targeted and more effective preinvestment resources, more accurate techno-economical

analysis leading to realistic cost-benefit projections, framing specific policies and financial incentives to attract private sector investment, and energy development policies. This activity will enhance existing activities by other agencies where they are operating and the tools further delivered through the UNEP Sustainable Technology Alternatives Advisory Network.

These products (and data) can be effectively used in national energy planning case studies exercises in the estimation of exploitable wind/solar resource potential under various scenarios, identification of potential regions of interest within the country and matching of resource availability with needs of population centres. The estimation of share of unserved energy demands that could be met by wind/solar energy in energy deficit pockets/regions can also be made. Other relevant analyses depending on available national data for electric grid lines, roads, etc. would also be included. The information can be marketed directly to investors who may not otherwise be reached.

Activity 4.1 Alternative business development scenarios in energy supply
This activity will demonstrate the outcomes of SWERA by developing and presenting solar and wind energy investment opportunities to investors. Marketing and outreach activity will require special efforts to reach investment decision-makers in venture capital companies, independent power producers, and utilities.

To create the business scenarios, information from other sources will need to be assembled. Drawing on existing national activities and GHG inventories, a number of demand growth scenarios would be selected. These will include national development plans. The work will consist of a review of available projections and selection of a few representative scenarios as opposed to a full mitigation analysis study. A nationally oriented technology mix will be identified that is a marketable to potential investors. This will include efficiency factors, nominal line loss characteristics, new load assumptions as required to convert the solar and wind energy resource data into usable potentials. Benchmark technologies will also be used for comparison purposes.

For participating countries, national stakeholders and particularly energy planners (including electrical utilities) will use the energy demand projections, solar and wind resource data, and engineering estimates of potential solar and wind based energy production as input to development of long term solar and wind development scenarios. These alternate business development scenarios can demonstrate the long term strategic potential of renewables, and serve as a basis for estimating GHG emission reduction potentials. Insights gathered from such exercises can stimulate policy initiatives designed to attract public and private investment in renewable energy projects.

Activity 4.2 Marketing and presentation of the alternative energy development projections to investors
The project will influence investment decisions by promoting alternative scenarios to business-as-usual investment especially in fossil fuel power plant. SWERA will present these scenarios directly to banks, financiers and developers to overcome informational barriers in solar and wind projects development for financing.

The various dissemination formats will include, limited hardcopy maps and reports, web-based access to information, CDROM information only, and CDROM information with user friendly tools. The core solar and wind information will be housed in the global archive (described in Activity Component 4), however, the collaborating agencies, with backup from INPE, TERI will be able to customise and modify the auxiliary data (electric grid lines etc) and provide customised services and products to regional clients. Confidentiality of auxiliary data will be negotiated in respect of national requirements and proprietary rights. New web technology, such as ArcIMS and ArcSDE, is changing how data is archived and shared, and how disseminators interact with expert users and regional centers, particularly those with access to high speed internet. The new technologies will significantly assist the regional agencies and commercial investor's ability to do value-added marketing based on the core data. Within the limited funds of this pilot project, the SWERA products will be promoted to investors and policy-makers through a series of targeted Seminars/Workshops for the potential investors. To obtain maximum mileage in terms of effective and faster dissemination, emphasis would be on the networking, e.g. within SAARC; BIMST-EC (Bangladesh, India, Mynamar, Srilanka, and Thailand Economic Cooperation); OPET (Organizations for the Promotion of clean and efficient Energy Technologies); and AIE (Asian Energy Institute) etc.

Expected results are:

- a demonstration of the value of the assessment activities
- an indication of the potential for increased estimates of the global potential for solar and wind energy utilisation.
- investment and policy changes

Activity Component 5. Management and Coordination

Activity 5.1 Coordination of project activities

UNEP/DTIE will coordinate the project with regional assistance from TERI as required. During the pilot project, TERI will provide services to countries in their regions as needed. Where appropriate, they will coordinate the activities among national partners and develop the technical capability; after SWERA to ensure that SWERA products are effectively and efficiently utilised to achieve accelerated and continued deployment of solar and wind energy systems.

Various tasks and responsibilities of the regional agencies can be summarized in the following manner:

- Coordination between SWERA team and national partners of the region so that activities and schedules are maintained.
- Assistance to national partners in data quality assessment & refinement.
- Work closely with NREL & Risø in the development of maps and receive incremental capacity building in assessment techniques including modeling.
- Provide capacity building to national organizations in use of resource maps and SWERA tools for energy planning.
- Dissemination of SWERA products and outreach to investors.

Activity 5.2 Meetings

Regional meetings will be held during project startup and during the development of the final report on the project. National assessments, regional mapping efforts, and integration/ extrapolation of global significance of the assessment will be developed through this exercise and recommendations made for further improvements in assessment methodologies and coverage. Sharing of information through common training exercises, sharing experiences and validation approaches during the assessment activities will enhance the quality of the assessments

TERMS OF REFERENCE FOR DLR

Outputs

The following outputs are envisaged for the DLR subproject:

- Maps and GIS data sets of monthly and yearly sums of Global Radiation and of Direct Radiation covering the land areas of Ethiopia, Kenya, Ghana, Bangladesh, India, Nepal, Sri Lanka, Western China and the North East of Brazil, with an expected accuracy of better than 10 % with respect to the annual sum of solar radiation, a spatial resolution of approximately 5x5 km per pixel (less for countries far from the subsatellite point which is 0°,0° for Meteosat 7 and 0°, 63° for Meteosat 5, e.g. the resolution for China will be approx. 15 km per pixel). An enhanced spatial resolution of approximately 1x1 km may be provided in some cases. The maps will be based on 3 years of time series data with a time resolution of 1 hour.
- Yearly hourly time series of Direct and Global Radiation for selected sites in each country. This data will be useful for detailed performance modeling and economic assessment, and within the project for comparison to ground measurements and to other satellite data retrievals. The sites will be selected during the project on the basis of the solar radiation maps. For India, mapping and times series retrieval will be done for internal validation purposes only.
- Documentation with respect to theoretical background, methodology, data processing and quality assessment for each country.

Not easily quantified but an output of the project as well is the improved knowledge, skills, and confidence on the part of project partners, which will enable them to identify situations in which high resolution solar mapping can contribute to national energy needs and to remove barriers for investment decisions;

Activity 1: Satellite Image Archive

An archive of images from the METEOSAT 5 and METEOSAT 7 satellites will be established covering the total area of all countries in Africa, Asia (and North East Brazil) that participate in the project. The archive will contain half-hourly images for 3 consecutive years that will be quality controlled and corrected, if necessary. Both the infrared and visible channel of the satellites will be recorded. The archive will be the basis for the detection of clouds that are of first order importance for the intensity of solar radiation on the ground (Activities 2 and 3). The archive will also serve as reference for the results of satellite data retrieved by the participants from India, China and Brazil (Activity 4). This activity will be concluded during the first 12 months of the project.

Activity 2: Atmospheric Data Archive

A second archive will hold the physical atmospheric data sets that define the solar radiation intensity on the ground as function of location and time. The archive will cover the following atmospheric data sets in order of their significance for ground radiation intensity (in brackets: spatial resolution, time resolution, representative period of data):

- Cloud Index (0.045°-0.15°, hourly means, 3 years)
- Aerosol Optical Thickness (0.8°x1°, monthly means, climatology)
- Precipitable Water (2.5°x2.5°, daily means, 3 years)
- Total Ozone (5° zonal, monthly means, 3 years)
- Transmission of Raleigh Atmosphere and Mixed Gases (O_2, CO_2, uniform and steady state standard atmosphere)

This activity will start after 7 months and will conclude after 18 months of the project.

Activity 3: Solar Radiation Data Processing

The data sets from the archive established within Activity 2 will be combined to high resolution maps and to site specific hourly time series of Global and Direct Radiation using the methodologies of DLR for Direct Radiation and of SUNY for Global Radiation. The data will cover the land areas of Ethiopia, Kenya, Ghana, Bangladesh, India, Nepal, Sri Lanka, Western China and the North East of Brazil. High resolution maps of monthly and yearly sums of solar radiation will be provided individually for each country as standard GIS data sets and as printed maps, showing the spatial distribution of the solar energy resource including microclimatic effects. For 10 selected sites in each country specified by latitude and longitude, annual hourly time series of Global and Direct Radiation will be provided as data files that may serve as basis for detailed performance and economic assessment studies, for comparison to ground measurements and other satellite data retrievals. Further data for individual sites may be processed later on request, placing an order to DLR for sites in Asia and Africa or to SUNY/ENTPE for sites in America. For India, mapping and times series retrieval will be done for internal validation purposes only.

Activity 3.1: Global and Direct Radiation Data Processing

This activity includes the preparation of maps, GIS data sets and hourly time series of Global Horizontal Irradiation (GHI) and Normal Direct Irradiation (NDI) for each country. The preparation of GHI and DNI data sets in all participating countries in Asia, Africa and America requires the collaboration of DLR and SUNY to combine their methodologies on an in-kind basis, which will take place in parallel to the Activities 1 and 2 during the first 6 months of the project. The production of the final country data sets and maps within Activity 3 will commence after the 12^{th} month of the project and end after the third year. Samples of data sets and preliminary results may be produced earlier within the first year of the project in order to show the principles and resolution of the data, but may not have the final quality and performance. The sequence of the countries to be analysed is still to be defined.

Activity 3.2: Quality Assessment

This activity includes comparison of the global and direct data sets and maps with existent ground measurements and other data sources, as far as available. Consistency checks of all data sets will be performed and the data will be flagged according to the results.

Activity 3.3: Documentation

A documentation of the theoretical principles, methodology, data processing, results and quality assessment will be elaborated individually for each country. The documentation will contain:

- Theoretical background of the generation of global and direct radiation data using satellite images and other remote sensing data sources.
- Description of equipment, software and data processing including satellite image retrieval, atmospheric data archive, methodology to yield GHI and NDI data sets and maps.
- Resulting maps and GIS data sets of monthly and yearly sums of Global Radiation and of Direct Radiation covering the land areas of Ethiopia, Kenya, Ghana, Bangladesh, India, Nepal, Sri Lanka, Western China and the North East of Brazil, with an expected accuracy of better than 10 % with respect to the annual sum of solar radiation, a spatial resolution of approximately 5x5 km per pixel (less for countries far from the subsatellite point which is (0°,0°) for Meteosat 7 and (0°, 63°) for Meteosat 5, e.g. the resolution for China will be approx. 15 km per pixel). An enhanced spatial resolution of approximately 1x1 km may be provided in some cases. The maps will be based on 3 years of time series data with a time resolution of 1 hour.
- Resulting hourly time series of Direct and Global Radiation for selected sites in each country. This data will be useful for detailed performance modeling and economic assessment, and within the project for comparison to ground measurements and to other satellite data retrievals. The sites will be selected during the project on the basis of the solar radiation maps. For India, mapping and times series retrieval will be done for internal validation purposes only.
- Description of quality assessment including the applied methodology, reference data and the results of quality assessment for each country.

Activity 4: Methodology Transfer to India, China and Brazil

Scientists from China and from India (TERI) will participate for three months (month 19-21) in the satellite image retrieval and data processing at DLR in order to learn how the DLR methodology works. Together with the documentation provided for their country by DLR, they will be enabled to transfer the DLR/SUNY methodology to their satellite and produce similar and consistent results for countries in East Asia that are not in the range of the DLR satellites. In a later phase, DLR personnel will backstop and supervise the implementation activities in China and India and help with the methodology transfer. With the participants from India, China and Brazil, data sets will be exchanged and evaluated in order to countercheck results derived from the INSAT, GOES and from the Meteosat satellites and to get consistency of solar radiation data and methodologies all around the globe.

A detailed work plan with individual responsibilities for the different activities will be prepared after the final selection of participating countries is made and the national teams are established.

TERMS OF REFERENCE FOR NREL -

INTEGRATION OF SWERA DATASETS WITH GEOGRAPHIC INFORMATION SYSTEM

Outputs

The following outputs are envisaged for the NREL Geographic Information System (GIS) subproject:

- Stand-alone GIS-based Toolkit to remove barriers among project stakeholders in using the integrated solar and wind resource assessment products.
- Standard GIS datasets will be developed from the results of the resource assessment activities. These datasets, in combination with terrain, population, and political boundary information, will remove information barriers.

Activity 1: Needs Assessment for In-Country Partner Participation

The needs of in-country partners will be assessed based on their ability to implement the GIS component of this project. The selection of an in-country partner, and the amount and type of incremental capacity building with these partners, will take into account the environment in which any current GIS capability resides. The existence and availability of databases, the capability to provide customer support and training, and finally, GIS infrastructure maintenance and sustainability will be considered. The regional collaborative agency will provide these services should an in-country partner not be available. The in-country or regional partner will work in close collaboration with the SWERA team to perform the necessary GIS related activities. Subject to needs and availability, these activities and resulting outputs could include:

- National survey of GIS information available for integration into project GIS
- Assessment of surveyed GIS databases for use in the SWERA Project, i.e. accessibility, accuracy, age, relevancy, format, conversion/importation requirements, constraints to use from issues related to accuracy, scale, precision, ownership, etc.
- Compilation/integration of the resulting selected set of country level GIS databases for the SWERA archive sites and GIS Toolkit.
- Establishment of additional archival locations and dissemination activities in collaboration with the SWERA archive/dissemination team

Activity 2: Develop Stand-alone GIS-based Toolkit

A GIS Toolkit will be adapted from available GIS technology for widespread distribution. Users will have access to the resource assessment data products in a format that allows for visualization and simple analysis. Specialized software or GIS expertise will not be required. The GIS Toolkit will be a standalone product for use on most personal computers and will be distributed via CD-ROM. All toolkits will include the geospatial solar and wind resource data along with selected GIS datasets of topography, population and land use for that area. Regional or country agencies will be responsible for customization services related to additional capability or privately held information.

Activity 2.1: SWERA Graphical User Interface.

A graphical user interface (GUI) will be developed to serve as the "front end" to the GIS Toolkit. This interface will be easy to use, will include on-line help, and will enable the user to access the program and associated data, and create graphical output. The programming environment will take advantage of object-oriented programming capabilities offered by several GIS vendors. A programming environment will be selected after careful evaluation of the options. The evaluation will include a consideration of the common GIS platforms in use throughout the world, the evolutionary nature of GIS programming and technology, and the specific needs of this project. This will ensure compatibility with the other project GIS data products to help ensure the long-term viability of the GIS Toolkit.

Activity 2.2: Integration of appropriate geospatial databases from the SWERA GIS. The successful analysis of geographically distributed phenomena requires appropriate geospatial databases. In addition to renewable energy resources and power generation and energy production potential for solar and wind technologies, the toolkit will incorporate existing GIS databases for topography, land use, and population density. Additional public domain data sets may be included at the recommendation of the regional and in-country partners, provided that these datasets exist, are readily available at nominal cost, and do not have restrictions on their use.

Activity 2.3: Algorithms and routines for the GIS Toolkit.
A subset of standard geospatial operations that are commonly performed within a GIS will be developed for the tool kit. These will include cartography, overlay, and proximity. Cartographic operations allow the user to produce hardcopy maps. Overlay operations allow the examination of resource related information with other factors that share a common geographic area. An example of an overlay operation would be the identification of areas where optimum solar energy resources intersect optimum economic conditions. Proximity operations allow the user to measure how far apart two or more features are. An example of a proximity operation would be to determine the distance from a load center to the nearest useable wind resource area.

Activity 2.4: User Manual and Training Materials for distribution with the GIS Toolkit. A user manual will be provided for distribution with the GIS Toolkit. Additionally, partner organizations will be trained on the use of the Toolkit. These organizations will then be available for continued or expanded training and user support with additional distributions of the Toolkit.

Activity 2.5: Beta Testing
Beta testing of the GIS toolkit product will be conducted by the SWERA team. Modifications and bug fixes will be based on beta testing results and feedback.

Activity 3: Develop Standard GIS Datasets
A standard suite of data products will be defined with SWERA partners and contributing agencies. These data products will be produced for each area within the overall project and will be freely distributed. Additional "non-standard" data sets may be developed by contributing agencies. The contributed data will be controlled by the contributor with use and distribution determined accordingly. Documentation and ISO compliant metadata will be developed as required for the data archive and dissemination system.

Activity 3.1: Geospatial Database Development.
Geospatial data developed from the results of the solar and wind resource assessment activities will be included in the GIS Toolkit and project archive. The resolution of the data will vary according to the resource assessment methodology used.

Activity 3.2: Metadata Development.
The documentation for the GIS datasets will be comprised of ISO compliant metadata. Metadata are "data about data" and include information on identification, quality, organization, spatial reference, entity and attributes, distribution and reference. The metadata will facilitate informed use of the data and allow searches to be conducted through the SWERA GSDI (Global Spatial Data Infrastructure) Clearinghouse Gateway.

Activity 3.3: Conversion and Integration of Selected Data Sets into GIS format. Additional digital data sets to be included in the archive and GIS Toolkit will support the analytical functions that can be performed within a GIS. These will include terrain, population information, and administrative boundaries. Partner agencies will provide land use, load centers, transportation and transmission corridor data according to the format and ownership status. These contributed data will be integrated at the discretion of the contributing partner. Data and associated information from ground based measurements will be included within the GIS where appropriate.

Activity 4: Assist in coordination of GIS related activities and products
The NREL GIS team will work in close collaboration with fellow SWERA participants to ensure that products integrated into the GIS meet the defined standards. We will also coordinate with the UNEP-GRID archive/dissemination team to ensure smooth integration of final products.

Activity 4.1: Selection of national contributing organization.
In collaboration with other parties from the SWERA steering committee, NREL will evaluate national organization suitability for SWERA project responsibilities. Should a national agency be selected, this agency will be responsible for country level GIS and dissemination activities and products from Activity 1. This organization will also have to work in a close collaborative relationship with the groups contributing to the wind and solar resource assessment subprojects.

Activity 4.2: Define appropriate supplemental data for inclusion in project
NREL will meet with contributing agencies to ensure that supplemental data incorporated into the SWERA project meet the overall project objectives.

ANNEX J TERMS OF REFERENCE FOR THE PROJECT MANAGER

Under the overall guidance of the Executive Coordinator, of the UNEP/GEF Coordination Office, direct supervision of the Director Technology Industry and Economics, and in collaboration with the Energy Coordinator for UNEP, the project manager will manage overall execution of the project and subprojects of the Solar and Wind Energy Resource Assessment.

(a) Co-ordinates all actions required for the effective implementation of the overall solar and wind energy resource assessment project and its sub-activities by:

(a) Facilitating the project steering committee to seek strategic advice on project implementation.

(b) Monitoring all collaborating agency's subproject implementation at all stages, including analyzing difficulties and taking remedial action; preparing and submitting reports to UNEP's GEF Coordination Office.

(c) Negotiating with international collaborating agencies changes to the to sub-project workplans and making necessary amendments to Project Documents and budgets.

(d) Securing support for national activities funded by the project and providing direct and indirect supervision and technical support, with an emphasis on promoting solar and wind energy planning and investment.

(e) Preparing and/or reviewing project written outputs and revising them as required.

(f) Requesting actions for contracting experts and ensuring satisfactory and expeditious completion of such actions.

(g) Preparing and/or reviewing various project administrative reports, e.g.., periodic progress reports, technical contractors' agency terminal reports, and, as requested, project status reports, fiscal reports and briefing notes.

(h) Promoting the outputs of the assessment and the methods used.

(i) Preparing for expansion of the resource assessment geographically and the addition of other renewable energy resources.

(j) Arranging for the completion of the sub-projects and main project, and ensuring all documents and financial accounts are finalized.

The project manager should have an advanced degree in a relevant scientific discipline (e.g., physics, meteorology, remote sensing), engineering, or equivalent. An advanced degree can be substituted for two years of relevant experience. General knowledge of and familiarity with renewable energy development issues, remote sensing, meteorology, geographic information systems, sustainable development in developing countries, and climate change issues.

At least 10 years experience in research or development/deployment program management, preferably with international agencies. Experience in developing and implementing GEF and/or renewable energy projects is beneficial. Work experience in developing countries and in projects with multiple international agencies is highly desirable.