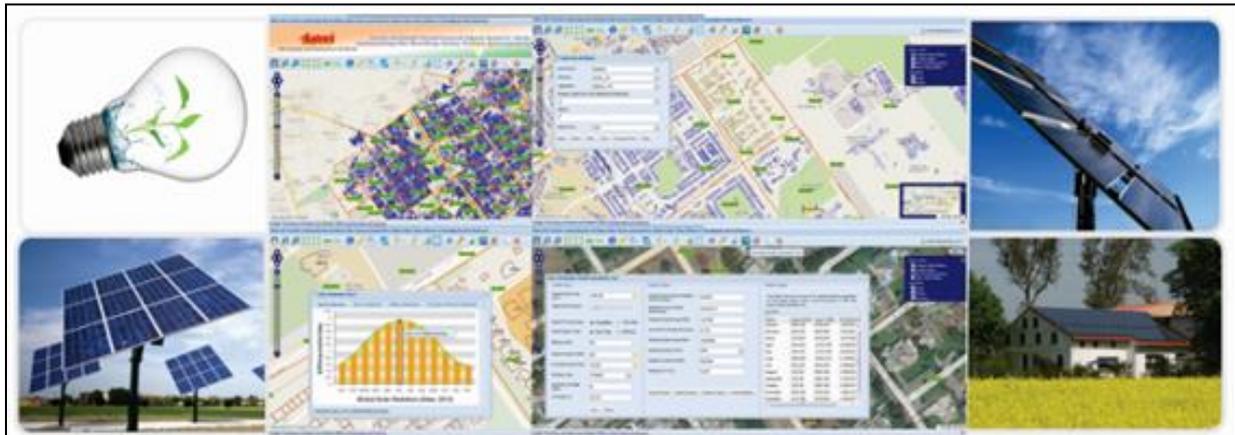


Development of Web-GIS Tool for estimating the Rooftop Solar Power potential for Indian Solar Cities

Prepared for

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For more information

Project Monitoring Cell

T E R I

Darbari Seth Block

IHC Complex, Lodhi Road

2468 2145

New Delhi – 110 003

India

Tel. 2468 2100 or 2468 2111

E-mail pmc@teri.res.in

Fax 2468 2144 or

Web www.teriin.org

India +91 • Delhi (0)11

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Final Project Report of “Development of Web-GIS Tool for estimating the Rooftop Solar Power potential for Indian Solar Cities”

Background

As the demand for renewable energy (RE) has grown, and so has the need to quantify the potential for these resources. Understanding the potential for a particular energy source can help informed policy decisions, educate consumers, drive technological development, increase manufacturing capacity, and improve marketing methods. In response to the desire to better understand the potential of clean energy technologies; several approaches have been developed to help inform decisions. One technology-specific example is the use of solar photo-voltaic (SPV) maps. A solar PV mapping tool visually represents a specific site and calculates PV system size and projected electricity production. Visual, web-based solar PV mapping products are increasing in prevalence. These tools quantify the potential for solar PV at a specific location to educate the user about the benefits of solar PV and its associated costs and savings.

Most of these existing tools such as, In My Backyard (IMBY), Solar Boston Map, San Francisco Solar Map, Berkeley Solar Map, PVWatts developed by National Renewable Energy Laboratory (NREL), Cambridge Solar Map developed by Massachusetts Institute of Technology (MIT) etc. have been developed as a part of the U.S. Department of Energy’s (DOE) Solar America Initiative (SAI). This initiative aims to make solar electricity from PV cost competitive with conventional forms of electricity from the utility grid by 2015 through R&D, and market transformation. Many of the 25 Solar America Cities, as part of the SAI, are pursuing solar mapping to educate their populaces. These maps empower a resident, business owner, or, decision maker to take the first step in analyzing the potential for solar PV at a particular location.

Rationale

Ministry of New and Renewable Energy (MNRE), Government of India (GoI) has launched Jawaharlal Nehru National Solar Mission (JNNSM), which targets 20,000 MW grid connected solar power development by 2022, and also considers the deployment of off-grid solar systems of 2000 MW. The Phase II of JNNSM targets deployment of 1,000 MW of rooftop solar PV projects both at off-grid and grid connected levels. Various solar PV systems have been installed across the country to meet the energy demand and to generate the clean and green energy. Many small Solar PV systems have been deployed in India for electrification where grid connectivity is either not possible or, extending the grid connection to that point is not cost effective and feasible. But in urban or, semi urban area, a large rooftop potential is available which otherwise is not used for any purpose, can be used to install the kilo-watt (kW) scale PV plants to cater the energy need, and hence reduce the extra burden on the transmission and distribution line which otherwise have to be redesigned and reinforced to meet the increased load demand. There are several tools available to estimate the solar rooftop potential, although there is a need of developing more accurate, user-friendly, intelligent and efficient tool which would be India specific, and meet the requirements of end users and planners, which can help in preliminary assessment of site specific rooftop solar PV potential.

Objective

To promote rooftop solar photovoltaic (SPV) systems, especially in Indian solar cities, there was a need for a tool to showcase solar resource potential in a user-friendly format so that users can investigate their locations of interest and perform pre-processed analysis. Geographic Information System (GIS) is the obvious tool to achieve this because it provides visual reference – a map of the entire city showing the buildings those have solar PV installation potential. An important part of every web-based GIS tool is its mapping or, visualization technology, which makes it possible to show data in the form of maps.

Hence, The Energy and Resources Institute (TERI) developed a first-of-kind cloud based open-source Web-GIS Tool for estimating Rooftop Solar Power potential for Indian Solar Cities. The main objective of this study was to develop a high performing and flexible Web-GIS tool to estimate the rooftop solar power potential for Chandigarh area. This initiative has been supported by Shakti Sustainable Energy Foundation (SSEF), and the strategic support is being provided by Chandigarh Renewal Energy Science and Technology Promotion Society (CREST), Ministry of New and Renewable Energy (MNRE), Solar Energy Corporation of India (SECI), and Confederation of Indian Industry (CII).

Study Area

For developing the Web-GIS tool, Chandigarh city has been considered as pilot city for the development of the tool. Chandigarh (Geographic Extent: 30.6632°N, 76.6827°E to 30.7922°N, 76.8301°E) is a city and union territory in India that serves as the capital of two states, Punjab and Haryana. The city of Chandigarh (as shown in Figure: 1) was the first planned city in India post-independence, as well as one of the solar cities under Ministry of New and Renewable Energy (MNRE), Government of India (GoI), and is also known internationally for its architecture and urban design.

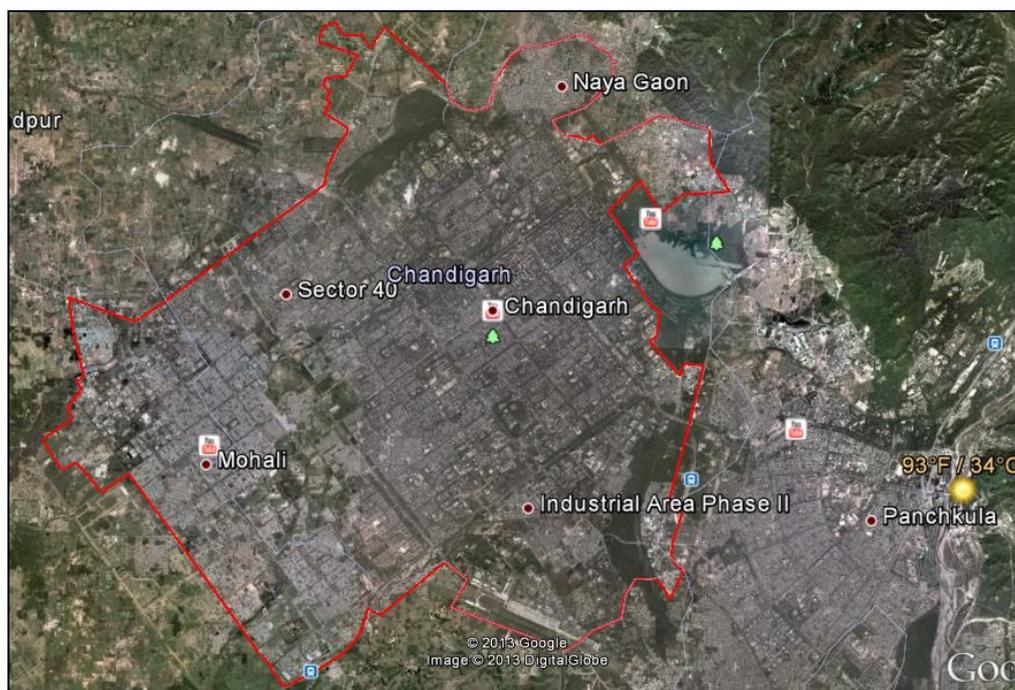


Figure 1: GIS Maps for Chandigarh Area (Data Source: Google Maps)

Note: Part of Union Territory (UT) of Chandigarh i.e., Mohali and Panchkula is being covered under this study with total area coverage of 108 sq-kms.

Work Packages

The proposed exercise includes the following work packages:

- Work Package I: Creation of Spatial and Non-Spatial (including financial aspects) Datasets in the context of Rooftop and Ground Survey (on a sampling basis) for data validations;
- Work Package II: Selection of an appropriate GIS Mapping Technology and Develop Software Architecture and Functions (including Spatial Analysis) to be incorporated into Web-GIS tool;
- Work Package III: Selection of an appropriate Database Management System (DBMS) and Creation of Geospatial Database;
- Work Package IV: Customizing the appropriate Development Platform, Develop a Rich Internet Application (RIA) and Hosting;
- Work Package V: Conducting Technical Training Programmes, and Stakeholders Workshops to disseminate the usage of this proposed Web-GIS tool.

Detailed Methodology

The methodology (refer Figure: 2) of the proposed study is elaborated in the steps below:

- Preparation of GIS base layers: The Pleiades satellite imagery (both the stereo-pair, and mono image) for the specified area of UT Chandigarh was procured and required image processing has been done for the images to create digital surface model (DSM) as well as creation of required vector data such as, building rooftop, sector boundary etc. The ground survey was also conducted in-order to validate the actual roof area information with processed data on a sampling basis.
- After preparing GIS base layers, the solar radiation available at each building rooftop has been calculated using ESRI ArcGIS Desktop tool having Spatial Analyst function. As an input of the Solar Radiation Analyst tool, a Digital Surface Model (DSM) of the city was prepared. Then, consider the bare earth DSM, and overlay that with the building heights using attributes available in the building footprints, which results in a three dimensional surface model of the city. On the basis of this prepared surface, the Solar Radiation Analyst tool was used to calculate the solar radiation availability for each rooftop. The Solar Radiation Analyst tool allows the analysts to model incoming solar radiation and take into account numerous factors, including variation in elevation, orientation (slope and aspect), the shadows cast by topographic features and changes with time of day or, year.
- After completing the analysis in desktop GIS software, the resulted solar radiation map was published via secured 'map web-service' which consist of base layers, and other layers of interest (e.g., rooftop area, solar radiation, possible system size and its cost considering various SPV technologies such as, Crystalline and Thin-Film, available incentives information on SPV systems both at national and state level etc.), to an open-source GIS Server (here, Geo-Server, and Map-Server) for use by the users of the Rooftop Solar Web-GIS tool. Since the calculations may take some additional

time to complete, therefore it was suggested to pre-process the analysis in order to deliver a more responsive and efficient web application.

- Wrapping the analytics into an easy-to-use Web-GIS tool was the next step. Presently there is great potential in new user interactive Application Programming Interfaces (APIs) such as Adobe Flex, Microsoft Silver-Light or, JavaScript which is a client-side technology, rendered by a web-browser. In this case, JavaScript API was used using which will enable developers to combine GIS based web services from a GIS Server with other web content and display it in a fast, visually rich mapping application that can be deployed over the web or, to the desktop.

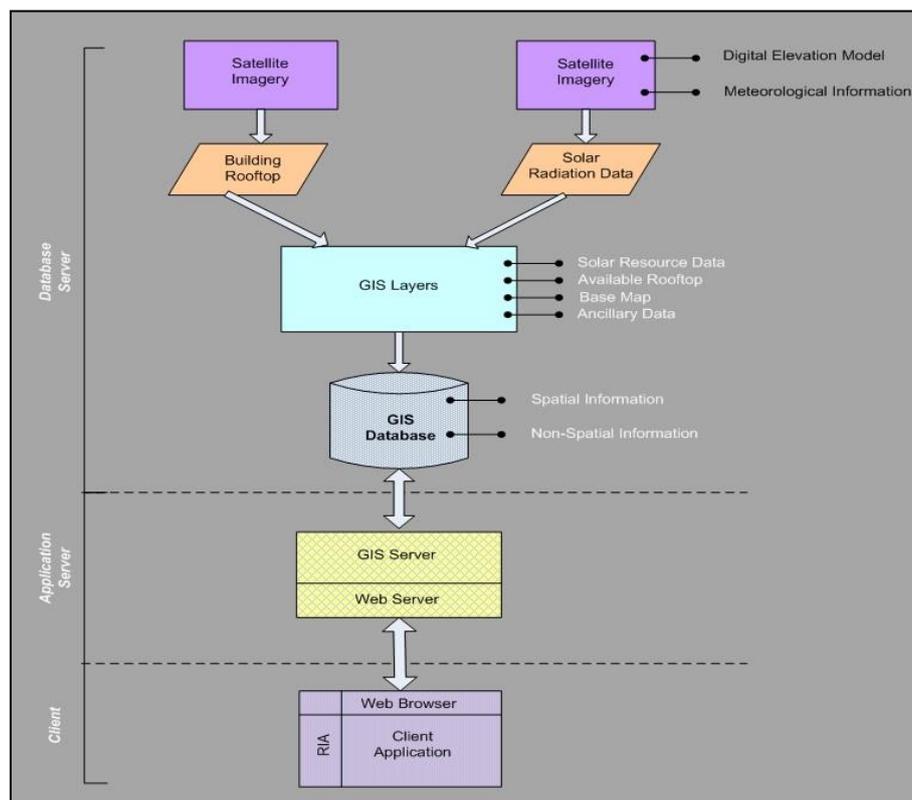


Figure 2: Methodology Flowchart

Note: For more details, please refer to the Inception Report of “Development of Web-GIS Tool for estimating the Rooftop Solar Power potential for Indian Solar Cities” at www.regisindia.org

Features of Open-Source Rooftop Solar Web-GIS Tool

- Publishing GIS Data using secured Map/Web-Services;
- GIS Navigation Toolbar for Web-Mapping Application;
- Customize Tools for Attribute, and Spatial Query;
- Customize Tool-set for Spatial Analysis;
- Report Generation Tools for both Normal Users, and Site Admin;
- Basic Editing Tools to edit, and update existing data and meta-data;

- Export of Queried database/results into an user required format such as, PDF and Excel etc;
- Attribute query tool, and report generation as per the user defined query;
- Spatial query tools, and report generation as per the user defined query;
- Various analysis tools based on application requirements. Utility Tools such as:
 - Identify Tool
 - Zoom Tools
 - Map Panning Tools
 - Map Navigation Tools
- Basic Query Tools;
- Advanced Query Tools with Multiple Parameters;
- Core Functionalities (refer Figure: 3):
 - Identify Solar Power Potential for each Building
 - Estimate Area-wise Solar Power Potential
 - Simulation Tool (including, PV system size, energy yield, cost, savings, payback etc.) for Solar PV Systems
- Tile Server Caching;
- Cloud-based Hosting Services.

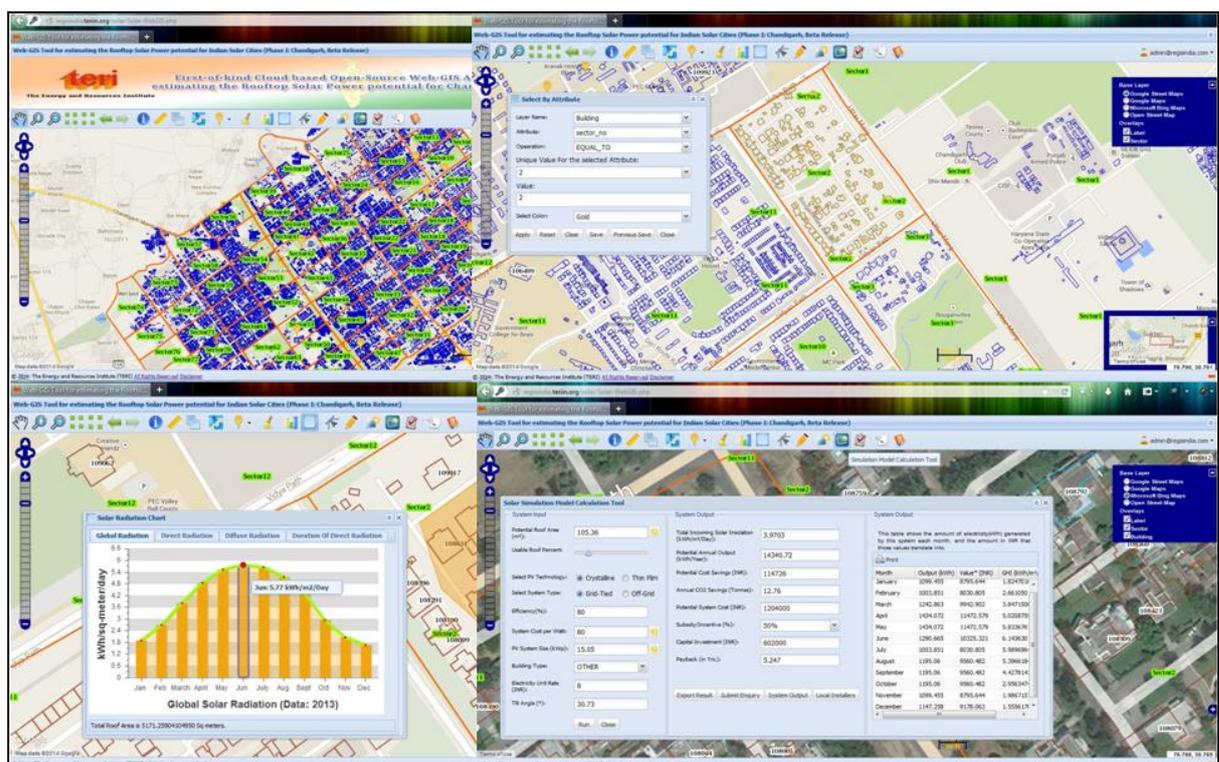


Figure 3: GIS Interface of Rooftop Solar Web-GIS Tool (Version 1.0) for Chandigarh

The official release of this tool (Version 1.0) is available at:

<http://regisindia.teriin.org/solar/Solar-WebGIS.php>. For more information about this ongoing project, and accessing the Renewable Energy Geo-Spatial Gateway of India (RE-GIS India), kindly visit at: www.spv4all.org | www.regisindia.org

Note: For more details, please refer to the Web-GIS Tool User Manual, and Interim Reports of “Development of Web-GIS Tool for estimating the Rooftop Solar Power potential for Indian Solar Cities” at www.regisindia.org

Principal Outcome(s) resulting from the Project

Rooftop Web-GIS Tool for India will be an ideal medium to showcase investors the logistics of rooftop solar energy investment. This tool will have the following benefits:

- The tool will enable users to estimate the rooftop solar power potential of selected area or, buildings for a particular location w.r.t. various SPV technologies (crystalline/thin-film)
- It will act as a Decision Support System (DSS) to carry-out the pre-feasibility assessment (meso-level) of putting rooftop PV system for a particular location;
- The Web-GIS tool will help users to communicate their expression of interest directly to the nodal agencies, as well as they can also contact local SPV installers;
- It will also assist users for the viability of any rooftop projects based on possible business models, and financial schemes available.

Beneficial at National Level

After successful demonstration of this proposed Rooftop Solar Web-GIS tool on a pilot-basis, the quantifiable and tangible benefits will be showcased for other cities too. This tool can work as a base platform, which can be customized for other cities by creating the GIS data layers for the target city and integrating those with the existing tool, without having any additional development efforts. Preliminary level of discussions has already been initiated with Ministry of New and Renewable Energy (MNRE), Ministry of Power (MoP), Government of India (GoI) for replicating Chandigarh model for other “Solar Cities” in the country. Upon development of the GIS database(s), and successful demonstration of the tool for few major cities in the country, the possibility of inclusion of this database into world resources such as, Global RE-Atlas etc. can be explored.

Additional Outcome(s)

- The entire software development life-cycle and GIS data creation process will be through as per the specified international standards such as, IEEE Standards Association (SA) Software Document Definitions (International Standards for Software Development), International Geospatial Interoperability Standards i.e., ISO Technical Committee 211 (ISO/TC 211) and Open Geospatial Consortium, Inc. (OGC)
- Develop a standardized software development framework which can be replicated further at later stage to demonstrate this similar concept universally for other cities.

Note: For more details, please refer to the Software Requirements Specifications (SRS) Document, and Software Design Specification (SDS) Document of “Development of Web-GIS Tool for estimating the Rooftop Solar Power potential for Indian Solar Cities” at www.regisindia.org

Knowledge Sharing and Outreach

National level Training Programmes and Conferences were conducted, while launching of the Rooftop Solar Web-GIS Tool/SPV4ALL Mobile Application/RE-Atlas Tool for Gujarat for wider dissemination, capacity building, and consumer awareness. In-addition, the outcome of the study was also presented in various national and international conferences, webinar, news articles, and periodicals across the globe. Furthermore, an interactive geo-spatial portal titled “Renewable Energy Geo-Spatial Gateway of India (RE-GIS India)”: www.regisindia.org has been developed dedicatedly for this project to disseminate the entire tool development progress including know-how such as, Calculation of Solar Resources Data using GIS, Validation of Solar Radiation Data etc. along-with some useful web-links which will help the stakeholders to get associated with.

Conferences:

First Stakeholders Workshop:

http://www.teriin.org/index.php?option=com_events&task=details&sid=617

Second Stakeholders Workshop:

http://www.teriin.org/index.php?option=com_events&task=details&sid=636

Training Programmes:

First Training Programme:

http://www.teriin.org/index.php?option=com_events&task=details&sid=623

Second Training Programme:

http://www.teriin.org/index.php?option=com_events&task=details&sid=641

Webinar: http://www.teriin.org/webinars/solar_webinar.php

SPV4ALL

Solar PV for all (SPV4ALL) is an initiative taken by The Energy and Resource Institute (TERI), and supported by Shakti Sustainable Energy Foundation (SSEF) to promote solar PV systems in India. The strategic support is being provided by Chandigarh Renewal Energy Science and Technology Promotion Society (CREST), and Ministry of New and Renewable Energy (MNRE), Government of India. For more information, kindly visit at:

www.spv4all.org

SPV4ALL Mobile Application:

The ‘SPV4ALL’ mobile application is initially developed for Android mobile devices (refer Figure: 4), using which users can estimate the electricity production of a grid-connected or, off-grid solar photovoltaic system based upon few simple input parameters. To use the solar

simulation tool under 'SPV4ALL' mobile application, user will need to select a location of interest on map either through find location or, using in-built GPS, specify the space available to install the solar PV system, and provide some basic information about the system cost, and electricity rate. 'SPV4ALL' mobile application calculates estimated value of electricity production, capital investment cost, CO2 savings, payback, find local solar PV installers etc. for the user define solar PV system.

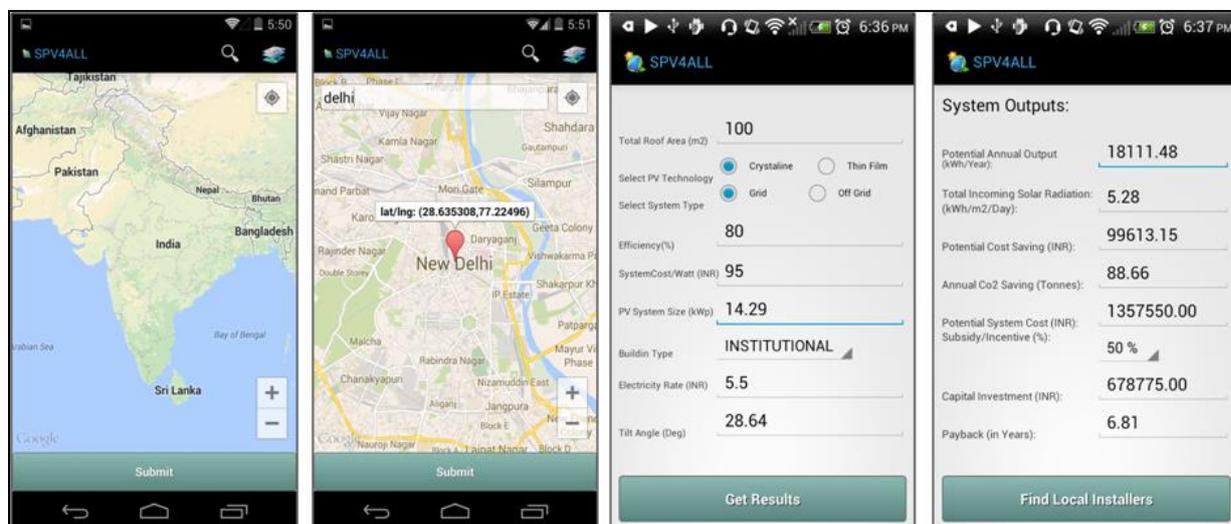


Figure 4: Android Interface of "SPV4ALL" Mobile Application (Version 1.0.1)

"SPV4ALL" Version 1.0.1 is available at Google Play Store:

<https://play.google.com/store/apps/details?id=org.teriin.spv4all&hl=en>

User Agreement

The views expressed and analysis put-forth in the RE-GIS India Website/Rooftop Solar Web-GIS Tool/SPV4ALL Mobile Application does not necessarily reflect views of the concerned authority(s). Rooftop Solar Web-GIS Tool/SPV4ALL Mobile Application is no substitute to an on-site assessment performed by a certified professional. Rooftop Solar Web-GIS Tool/SPV4ALL Mobile Application is a remote evaluation tool, based on topographical surveys, information models, and simulation methodologies, and results may be unavailable or, inaccurate due to issues including, but not limited to, partial sample obsolescence, excess of vegetation or, non-modeled obstructions, incomplete or, corrupted databases, incomplete or, corrupted GIS layers, undetectable partial obstructions based on survey resolution, and force majeure. Hence, the concerned agency(s) does not guarantee the accuracy of any data included in this publication and product nor, does it accept any responsibility for the consequences of its use. RE-GIS India Website/Rooftop Solar Web-GIS Tool can be best viewed at (1280 x 1024) resolution with Chrome 14.0/Internet Explorer 9.0/Mozilla Firefox 4.0, and higher, whereas SPV4ALL Mobile Application is developed for the Android platform.

About TERI

The Energy and Resources Institute (TERI) was formally established under the Registrar of Society in 1974 with the purpose of tackling and dealing with the immense and acute problems that mankind is likely to be faced with in the years ahead - on account of the gradual depletion of the earth's finite energy resources which are largely non-renewable and on account of the existing methods of their use which are polluting. While in the initial period the focus was mainly on documentation and information dissemination activities, research activities in the fields of energy, environment, and sustainable development were initiated towards the end of 1982. The genesis of these activities lay in TERI's firm belief that efficient utilization of energy, sustainable use of natural resources, large-scale adoption of renewable energy technologies, and reduction of all forms of waste would move the process of development towards the goal of sustainability.

Over the years the Institute has developed a wider interpretation of this core purpose and its application. Consequently, TERI has created an environment that is enabling, dynamic and inspiring for the development of solutions to global problems in the fields of energy, environment and current patterns of development, which are largely unsustainable. The Institute has grown substantially over the years, particularly, since it launched its own research activities and established a base in New Delhi, its registered headquarters. The central element of TERI's philosophy has been its reliance on entrepreneurial skills to create benefits for society through the development and dissemination of intellectual property. The strength of the Institute lies in not only identifying and articulating intellectual challenges straddling a number of disciplines of knowledge but also in mounting research, training and demonstration projects leading to development of specific problem-based advanced technologies that help carry benefits to society at large.



The Energy and Resources Institute

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