GeoSpatial Technology for Solar Energy in India

Space technology, Solar calculator & Rooftop potential

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National Institute of Advanced Studies, Bangalore, India

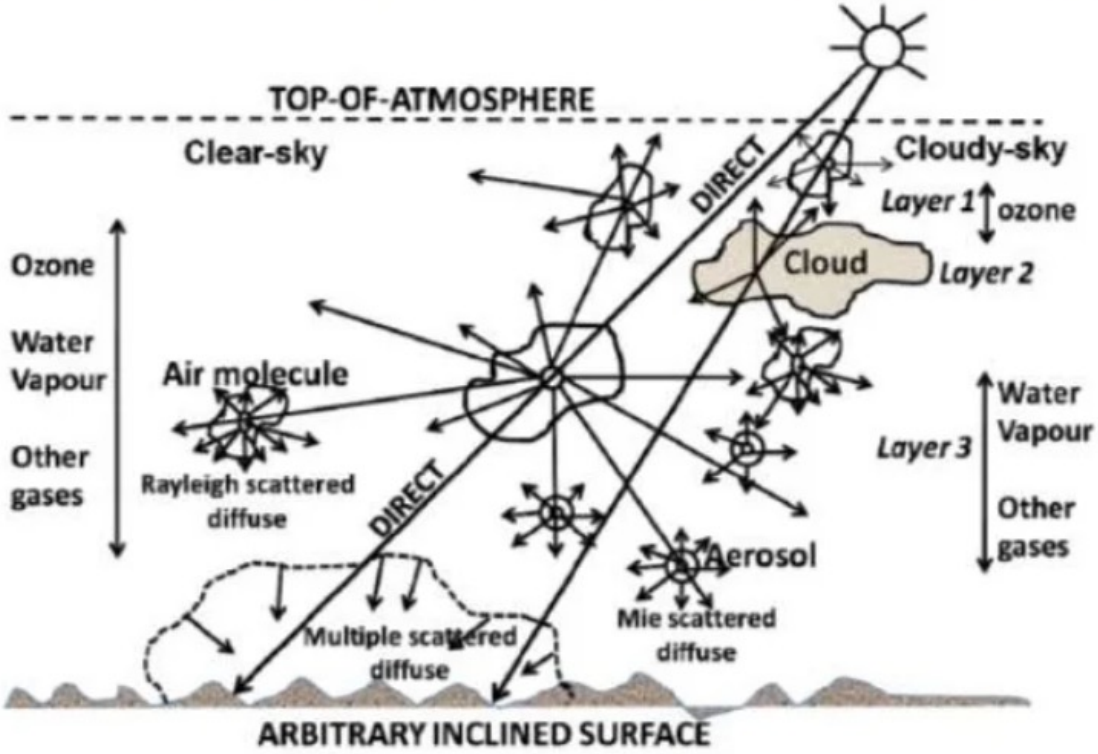
Background

- Ministry of New and Renewable Energy (MNRE), Government of India, has initiated Solar Cities program to support / encourage Urban Local Bodies to prepare Road Map towards Solar Cities.
- NITI Aayog has initiated representation of power sector including solar energy potential and plants on Geospatial domain with scope for Analytics
- Geographic location of the city, Variation in elevation, orientation (slope & Aspects) and shadows cast by topographic features as well as Urban structures effect the amount of insolation received at different locations
- The Solar City aims at minimum 10% reduction in projected demand of conventional energy from renewable energy sources as well as energy-efficient instruments.
- Under segment of Utility Grid Power including rooftop had a target of 20,000 MW in 2017-2022 Plan (seci.gov.in) & MNRE prioritized first 20 Smart cities and further extension to 100 Smart cities

Interaction of Solar Radiation and Atmosphere

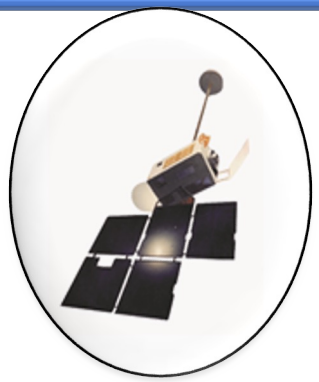
A part of solar radiation that is neither reflected nor scattered, and which directly reaches the surface, is the **direct radiation**.

Detailed information about solar radiation availability at any location is essential for the design and economic evaluation of a solar energy system.

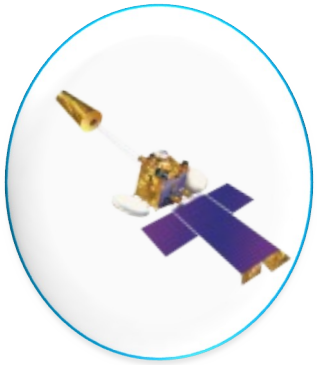


A part that is scattered by the atmosphere, and which reaches the ground, is the **diffuse radiation**.

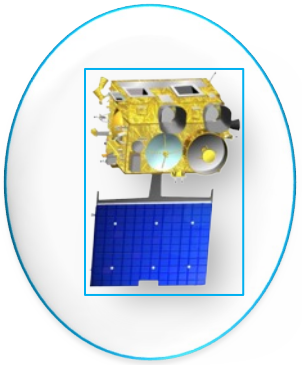
VEDAS
Visualisation of Earth Observation Data and Archival System
Beta



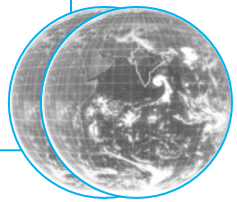
2 to 3 bands



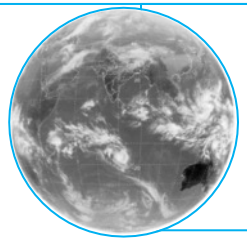
3 to 6 bands



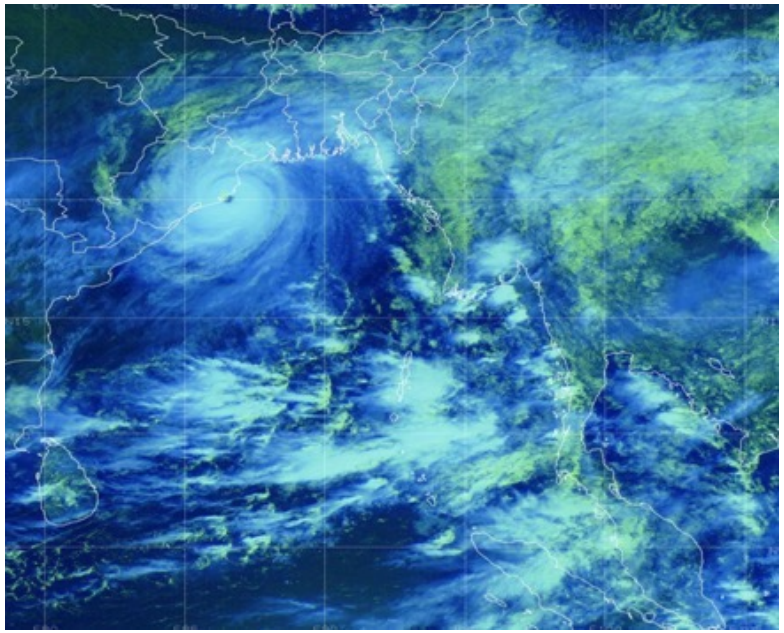
INSAT 1 Series (1983)
2 Bands (8 km)
4 images per day



INSAT 2 Series (1990)
3 Bands
4 images per day



INSAT 3 Series (2013)
6 Bands (1 km)
19 Channel Sounder
48 images per day



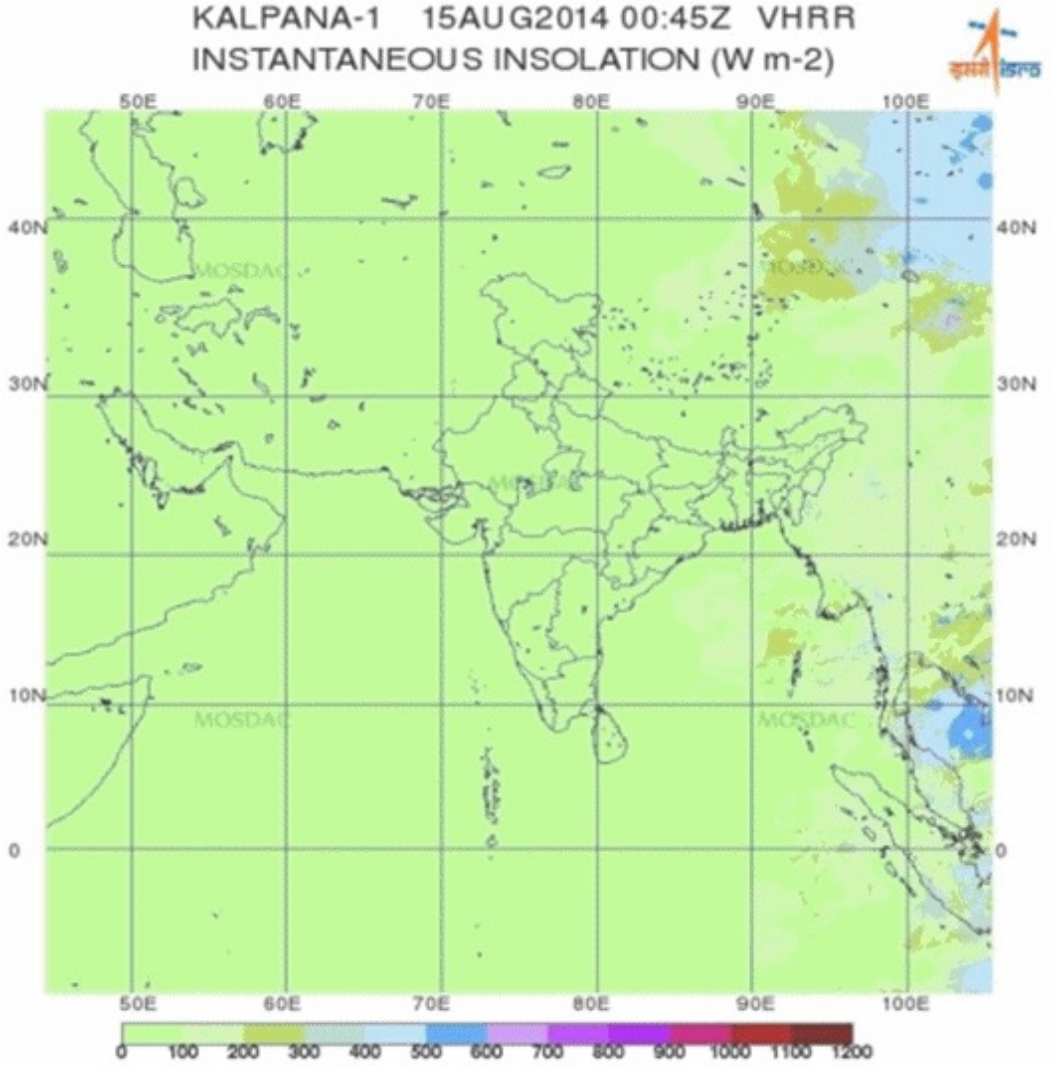
- Feeding to Weather Forecasting service

- The processing capabilities are indigenously developed and are operational.
- Many important weather parameters are being measured from INSAT-3D and 3DR, provided on near real-time basis

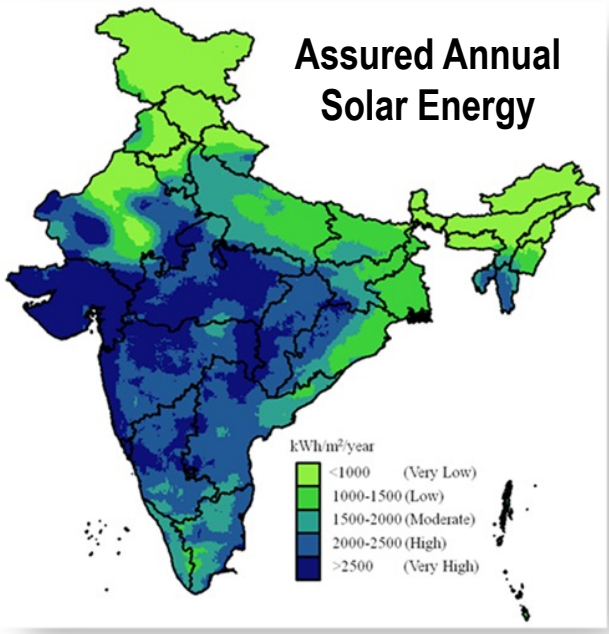
Complete Ecosystem for Weather Forecasting

Solar Energy Modeling & Harnessing

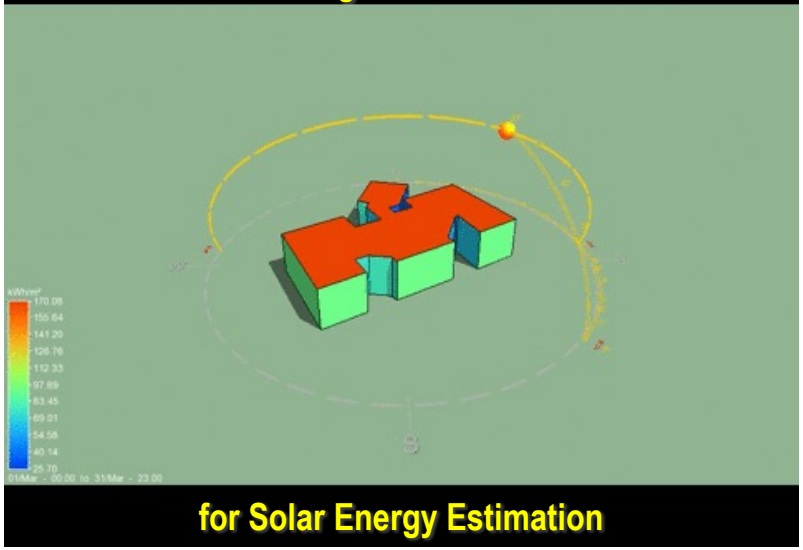
Solar Energy Monitoring using INSAT system

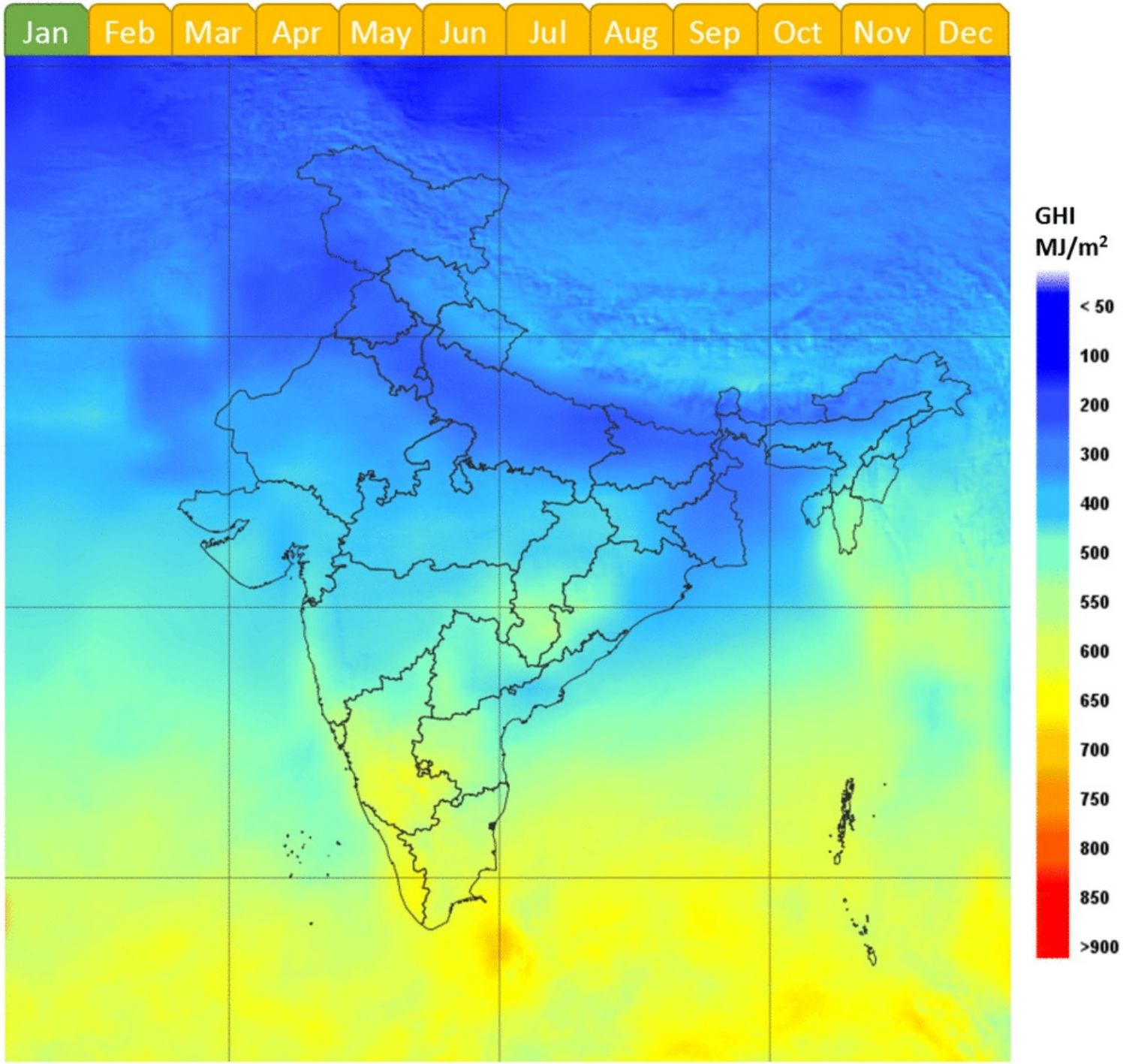


Assured Annual Solar Energy

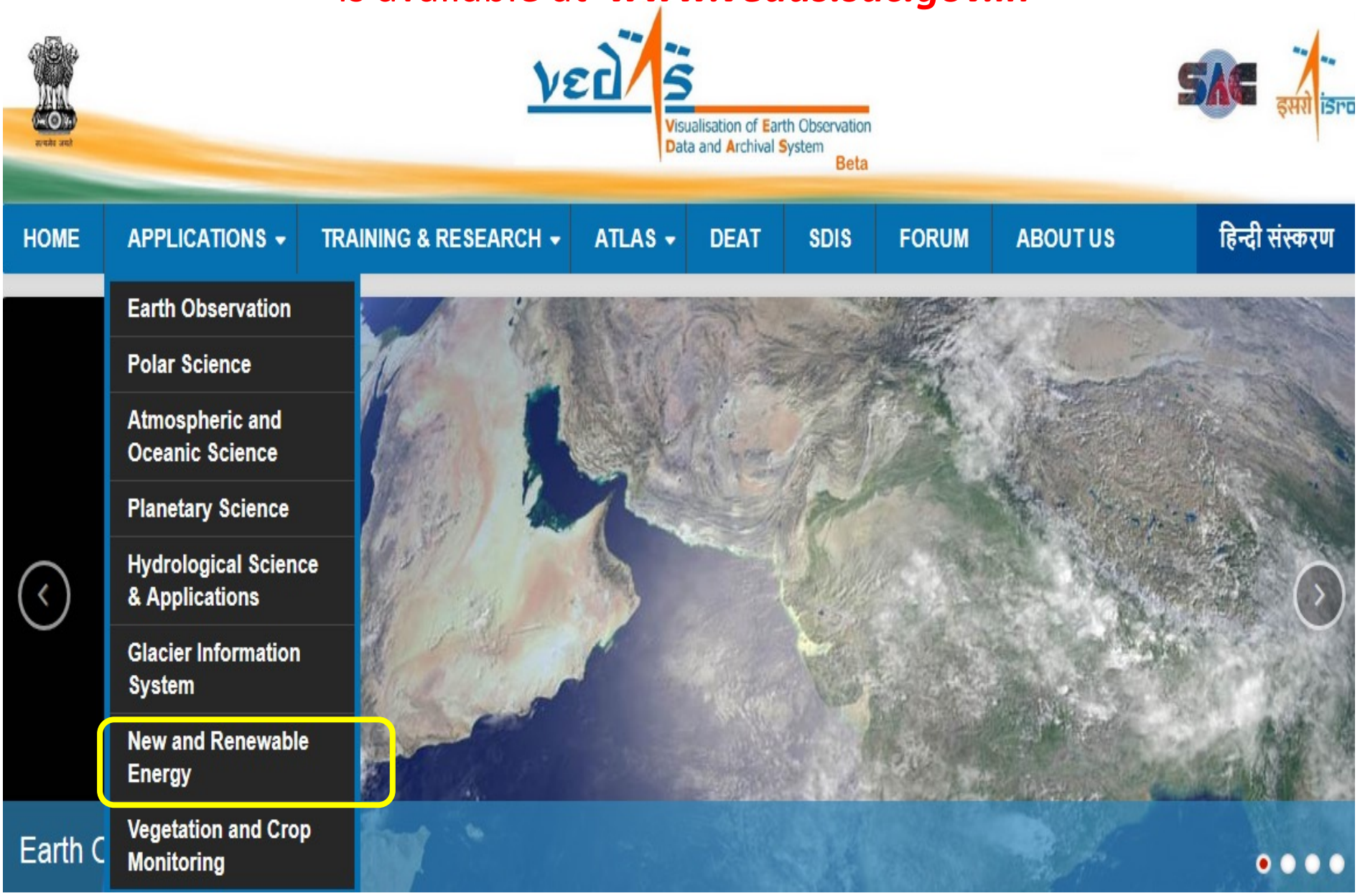


Simulating Sun Illumination for Solar Energy Estimation




Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
GHI
MJ/m²
< 50
100
200
300
400
500
550
600
650
700
750
800
850
>900

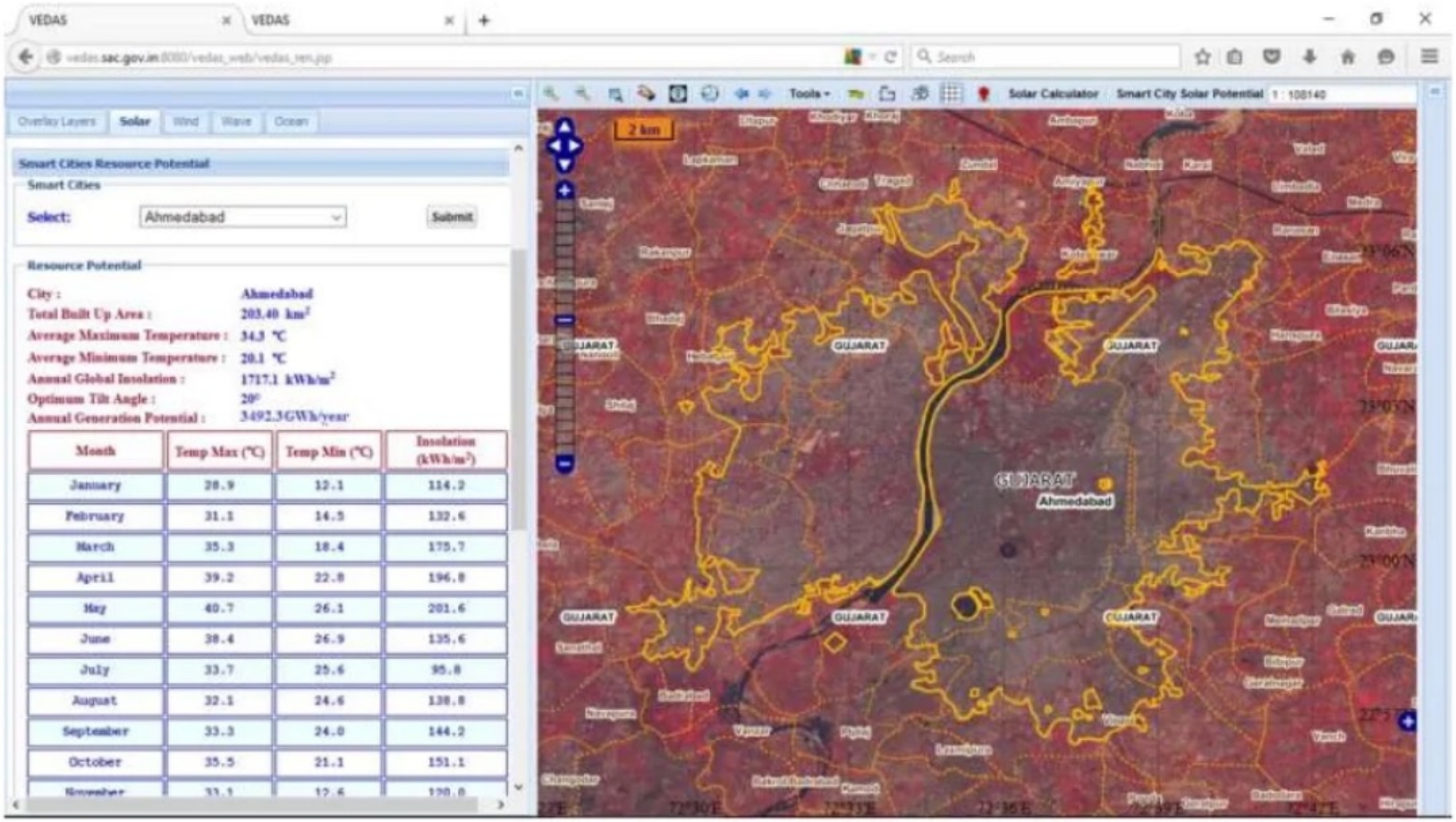
Digital Atlas of Renewal energy like Solar, Wind and Wave Energy is available at ***www.vedas.sac.gov.in***



Available Potential for Roof-top PV in Smart Cities

- Total Built-up Area of 98 Cities: **6,360.92 km^2**
- Total Roof Area (assuming 25% of built-up area is covered by buildings): **1590.24 km^2**
- Total Suitable Roof Area (using constant proportion method, assuming 25% of total roof area is suitable for PV): **397.56 km^2**
- Total Solar Energy Output on Suitable Roof Area (16% efficiency of solar PV module): **103,510.29 GWH / Annum**
- Available Peak Power Generation Potential (10 m^2 power per kW power and 80% system performance ratio): **31 GWp**

Solar Energy Potential of Smart Cities (98) and Solar Cities (60)



Visualisation of Earth Observation Data and Archival System
Beta

Geospatial Requirements

1. 3D Building rooftops
   - For potential Area and height of the building
2. Large Scale Urban Land Use / Land Cover
   - **For potential building like public/semi public areas**
3. City administrative units (like wards)
   - **To audit the ward wise power generation estimate and maintenance**
4. Digital Elevation model
5. Solar radiation/insolation computation algorithms/ S/w tools

Total direct insolation (Dir_{tot}) for a given location is the sum of the direct insolation ($Dir_{\theta,\alpha}$) from all sun map sectors:

- $Dir_{tot} = \Sigma\ Dir_{\theta,\alpha}$ (1)

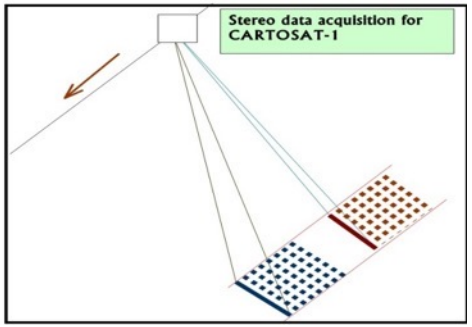
The direct insolation from the sun map sector ($Dir_{\theta,\alpha}$) with a centroid at zenith angle (θ) and azimuth angle (α) is calculated using the following equation:

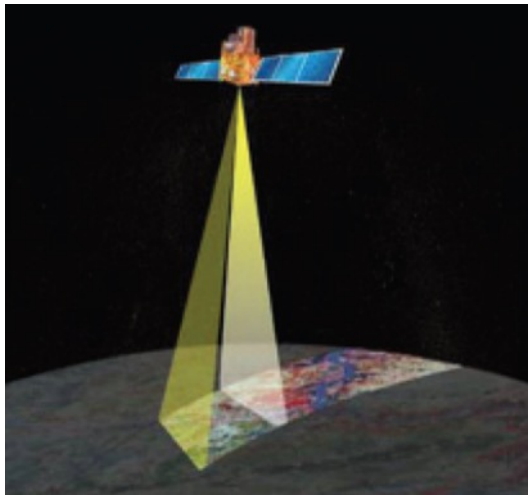
- $Dir_{\theta,\alpha} = S_{Const} * \beta^{m(\theta)} * SunDur_{\theta,\alpha} * SunGap_{\theta,\alpha} * \cos(AngIn_{\theta,\alpha})$ **(2) where:**
  - S_{Const} **— The solar flux outside the atmosphere at the mean earth-sun distance, known as solar constant. The solar constant used in the analysis is 1367 W/m². This is consistent with the World Radiation Center (WRC) solar constant.**
  - **β — The transmissivity of the atmosphere (averaged over all wavelengths) for the shortest path (in the direction of the zenith).**
  - **m(θ) — The relative optical path length, measured as a proportion relative to the zenith path length (see equation 3 below).**
  - $SunDur_{\theta,\alpha}$ **— The time duration represented by the sky sector. For most sectors, it is equal to the day interval (for example, a month) multiplied by the hour interval (for example, a half hour). For partial sectors (near the horizon), the duration is calculated using spherical geometry.**
  - $SunGap_{\theta,\alpha}$ **— The gap fraction for the sun map sector.**
  - $AngIn_{\theta,\alpha}$ **— The angle of incidence between the centroid of the sky sector and the axis normal to the surface**

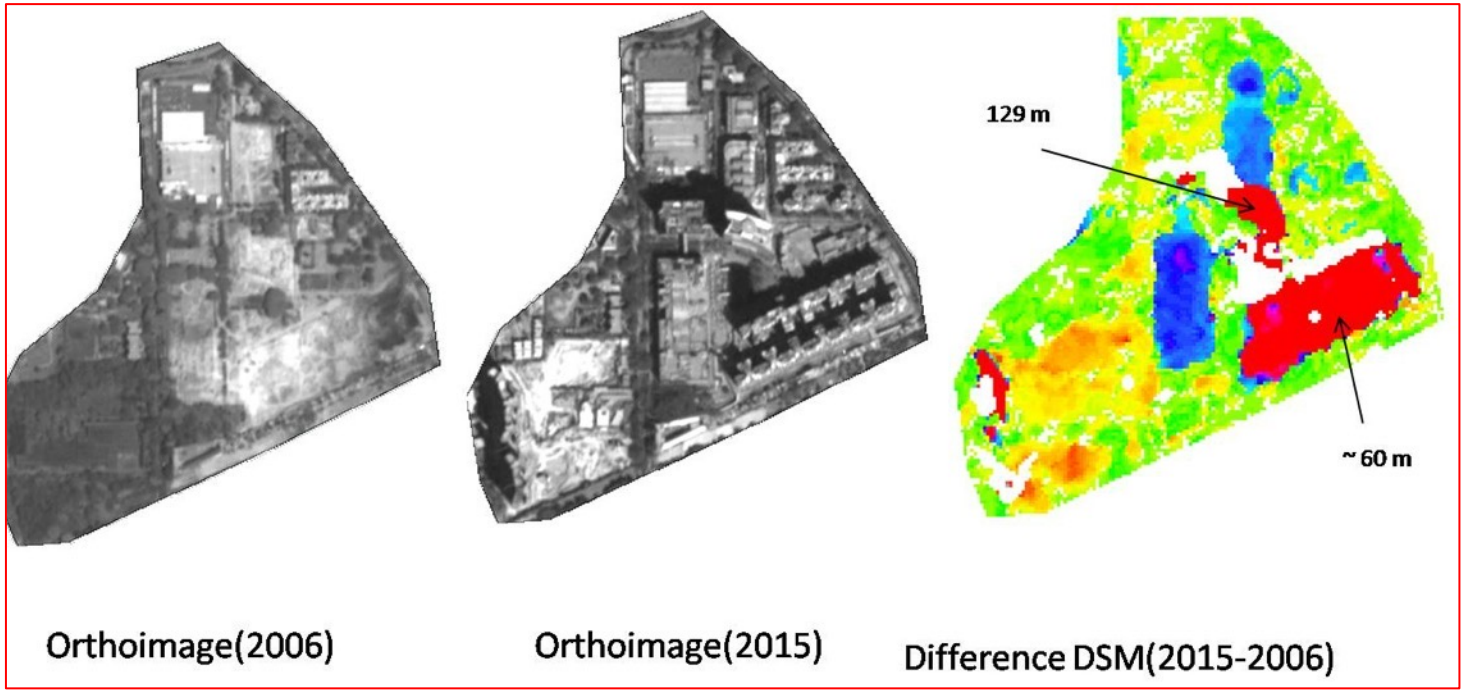
CARTOSAT-1 Stereo Mission

- CARTOSAT-1 was an important high-resolution imaging system with FORE and AFT cameras, tilted in along track direction by 26^0 and -5^0 w.r.t nadir thus forming stereo pair.
- GSD of 2.5m and swath of about 27Km.

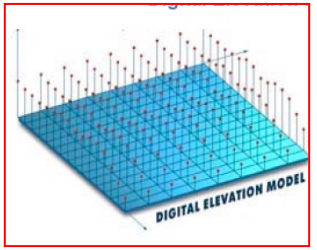
Stereo (pair)

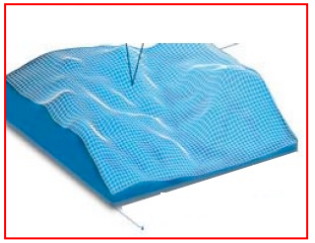




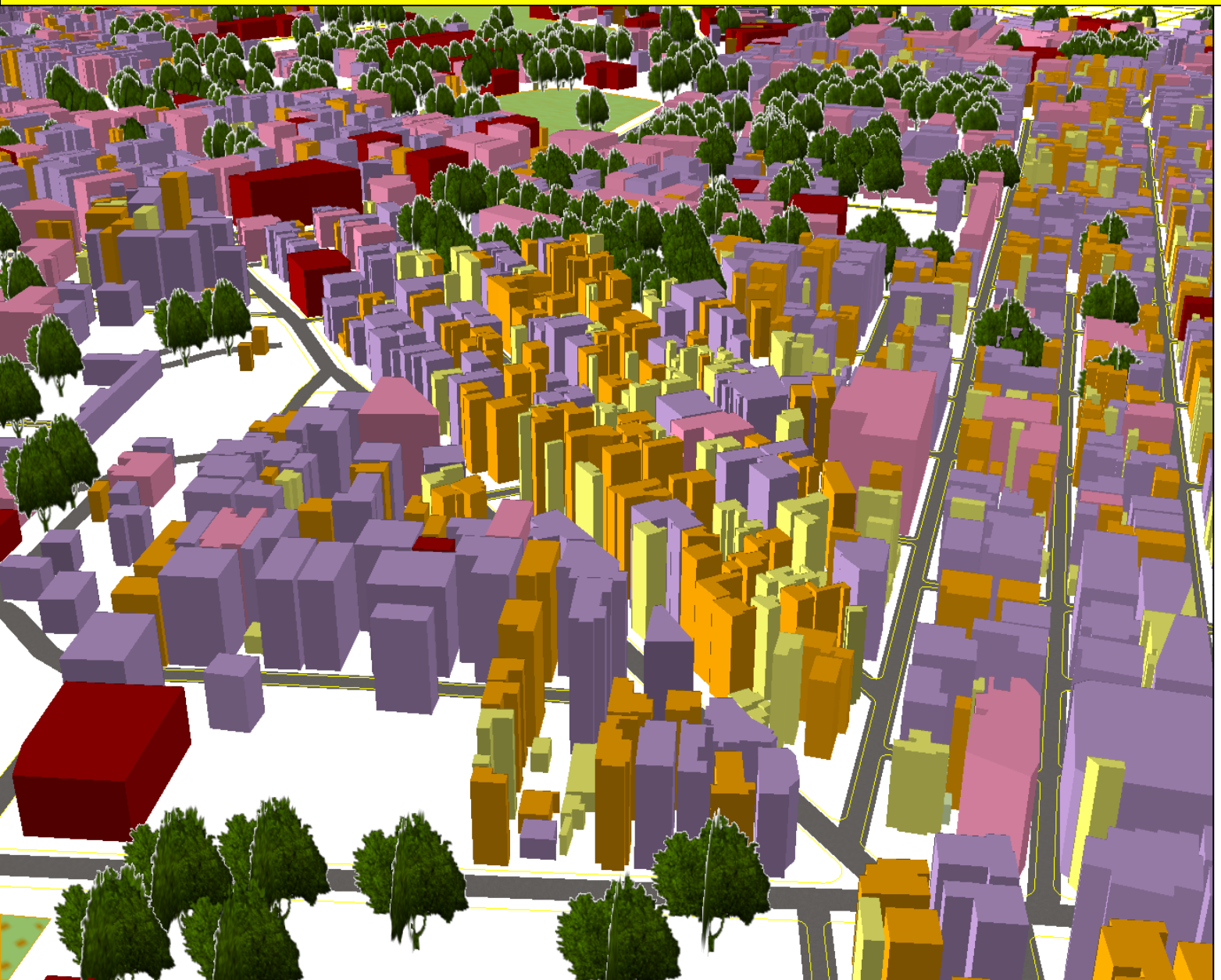


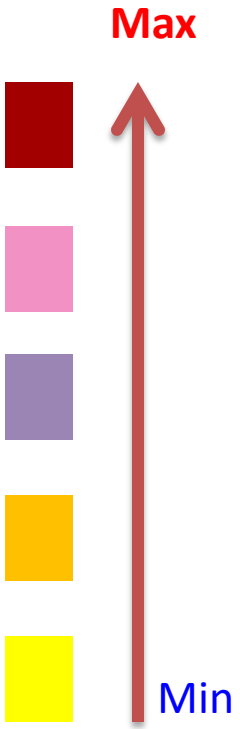
Digital Elevation Model



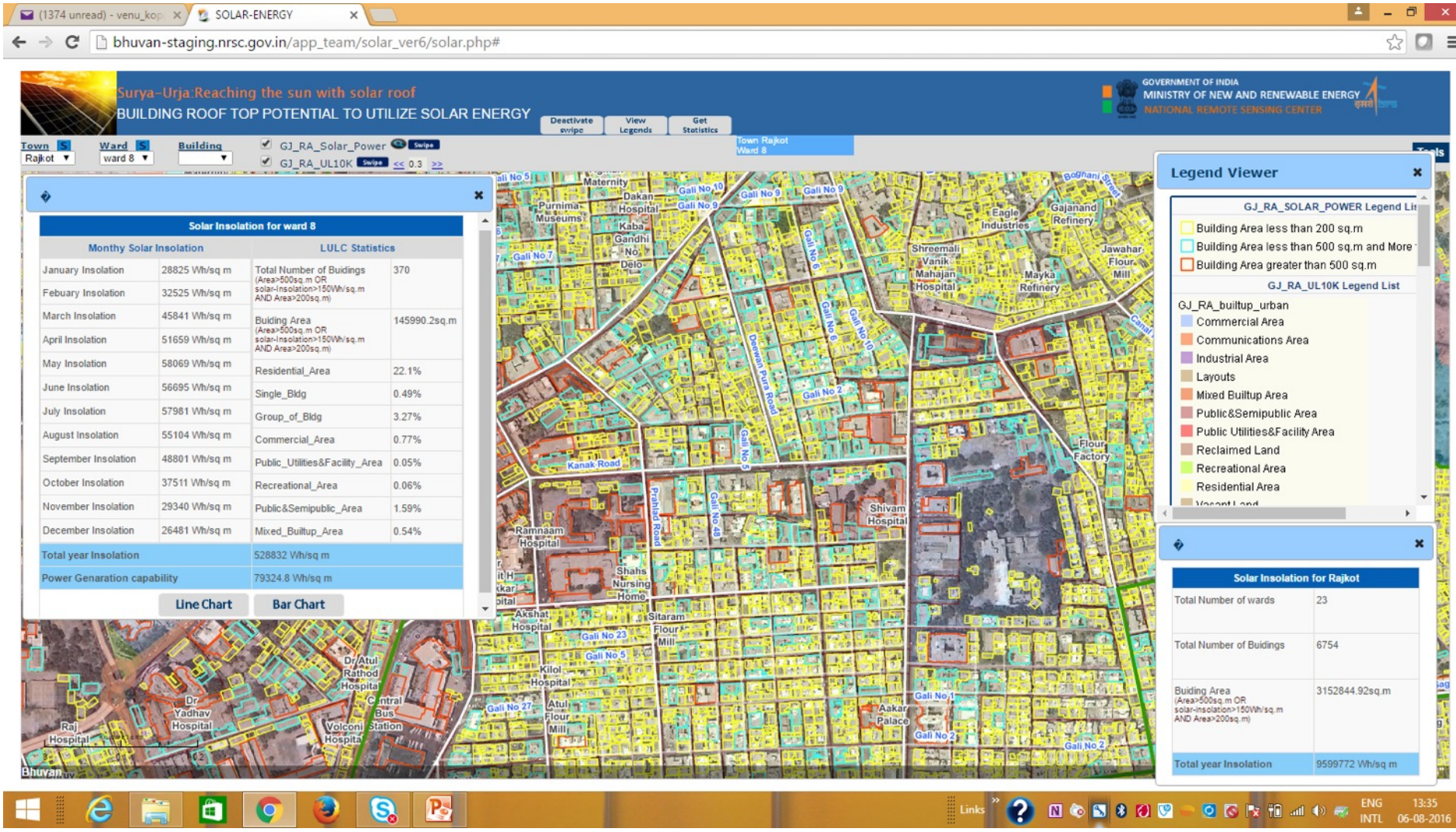


Processed data - Potential Building Roof Tops



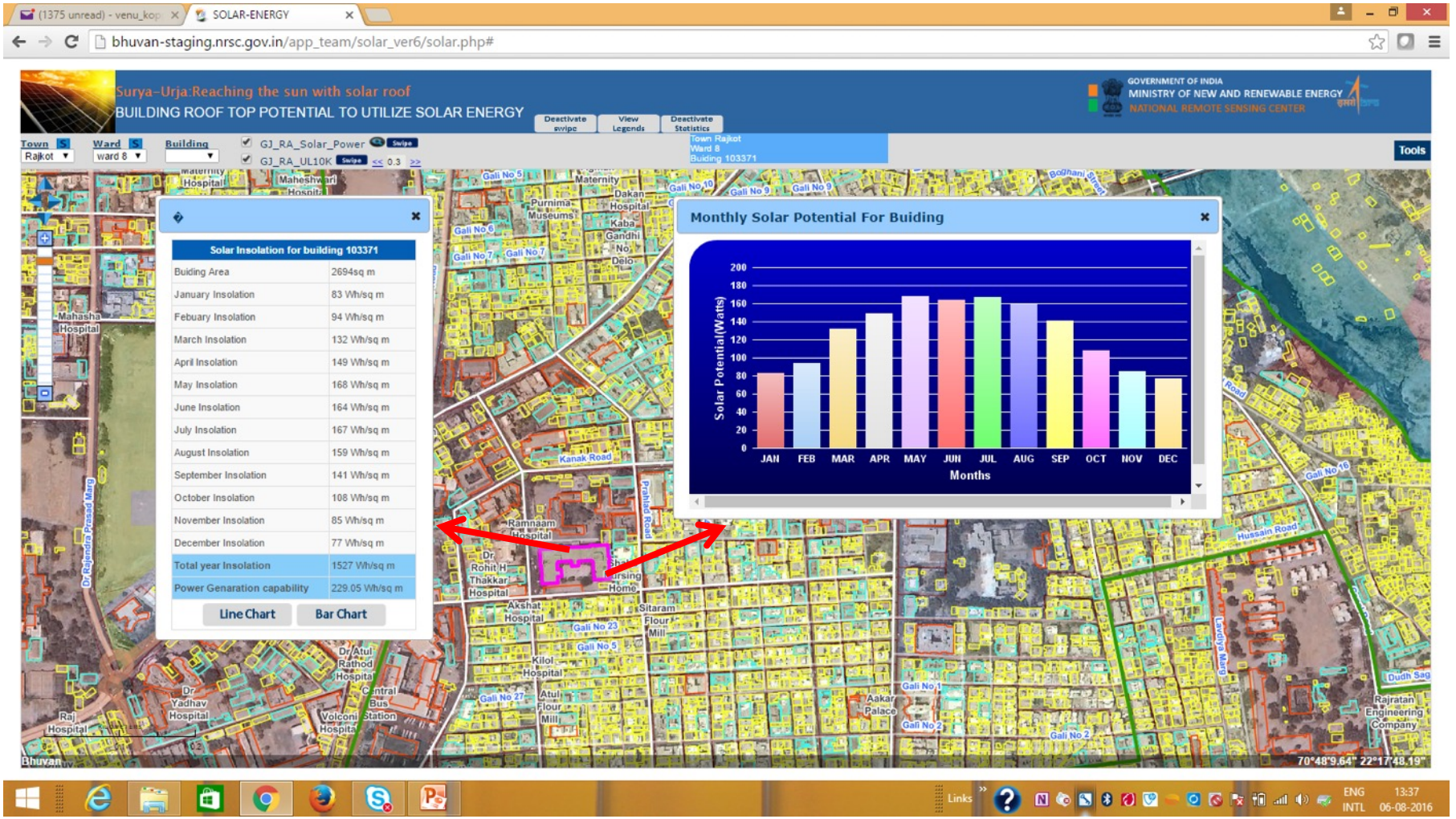


Building rooftop solar Potential – Bhuvan Geoportal



1. Integrated Building rooftop solar potential with Urban Land use, Wards boundaries.
2. buildings rooftop area > 500 sq. m with min 150 wh/m2 in summer month
3. 200 sq.m < Building rooftop area < 500 sq.km with min 150 wh/m2 in summer month

Building rooftop solar Potential – online analytics



1. **Query system & analysis**
   - City wise
   - Ward wise
   - Individual building wise

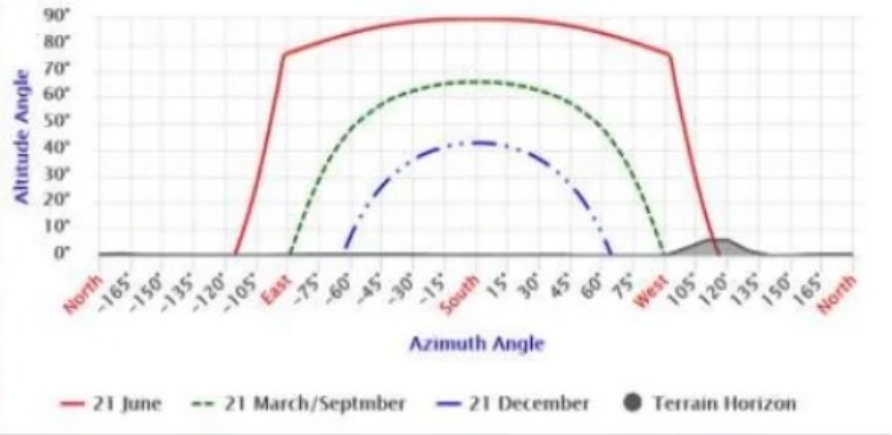
1. Scientific assessment for feasibility of implementation of Solar city project.
2. DPR preparation and budget estimates
3. Citizens can access the scientific data

Solar Energy Potential of Ahmedabad City

Solar Energy Potential of Ahmedabad City

City:	Ahmedabad
Total Built Up Area:	203.4 km^2
Average Maximum Temperature:	34.3 °C
Average Minimum Temperature:	20.4 °C
Solar Panel Tilt Angle:	21° [Summer : 1°, Winter : 40°]
Annual Global Insolation:	1717.1 (kWh/m^2)
Annual Generation Potential:	3492.3 GWh/year
Peak Power Generation Potential:	1271.25 MWp

Sun Path and Sky View



Insolation and Temperature

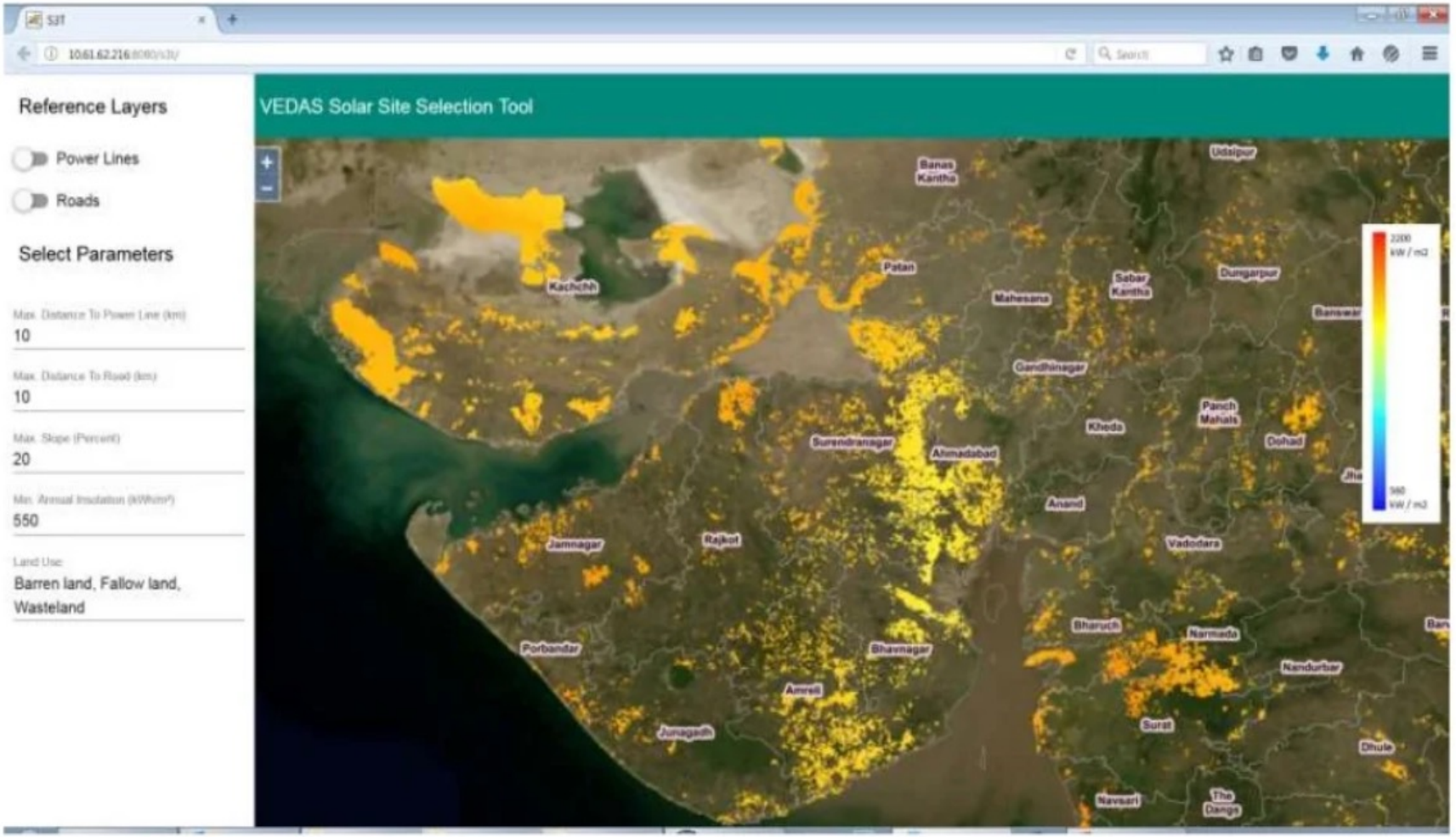


Day Length



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Interactive Solar Site Suitability Analysis App



Visualisation of Earth Observation Data and Archival System
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Android Solar Calculator App

Tabular Description



Graphical Representation

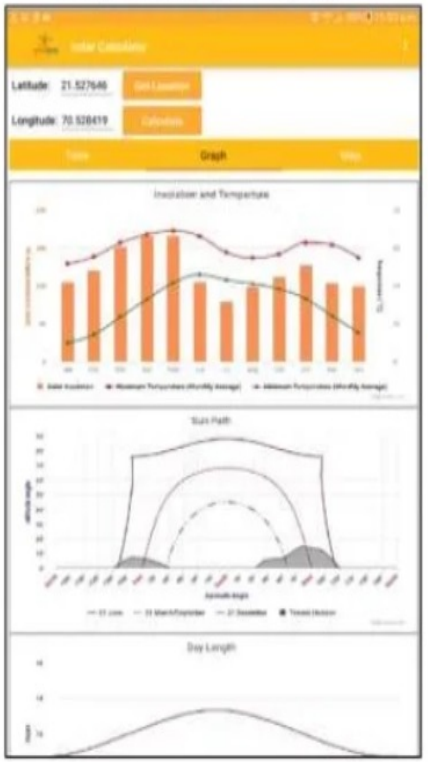
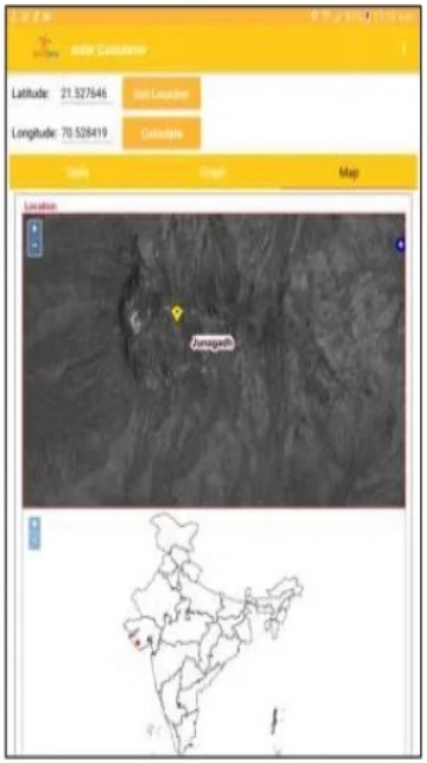
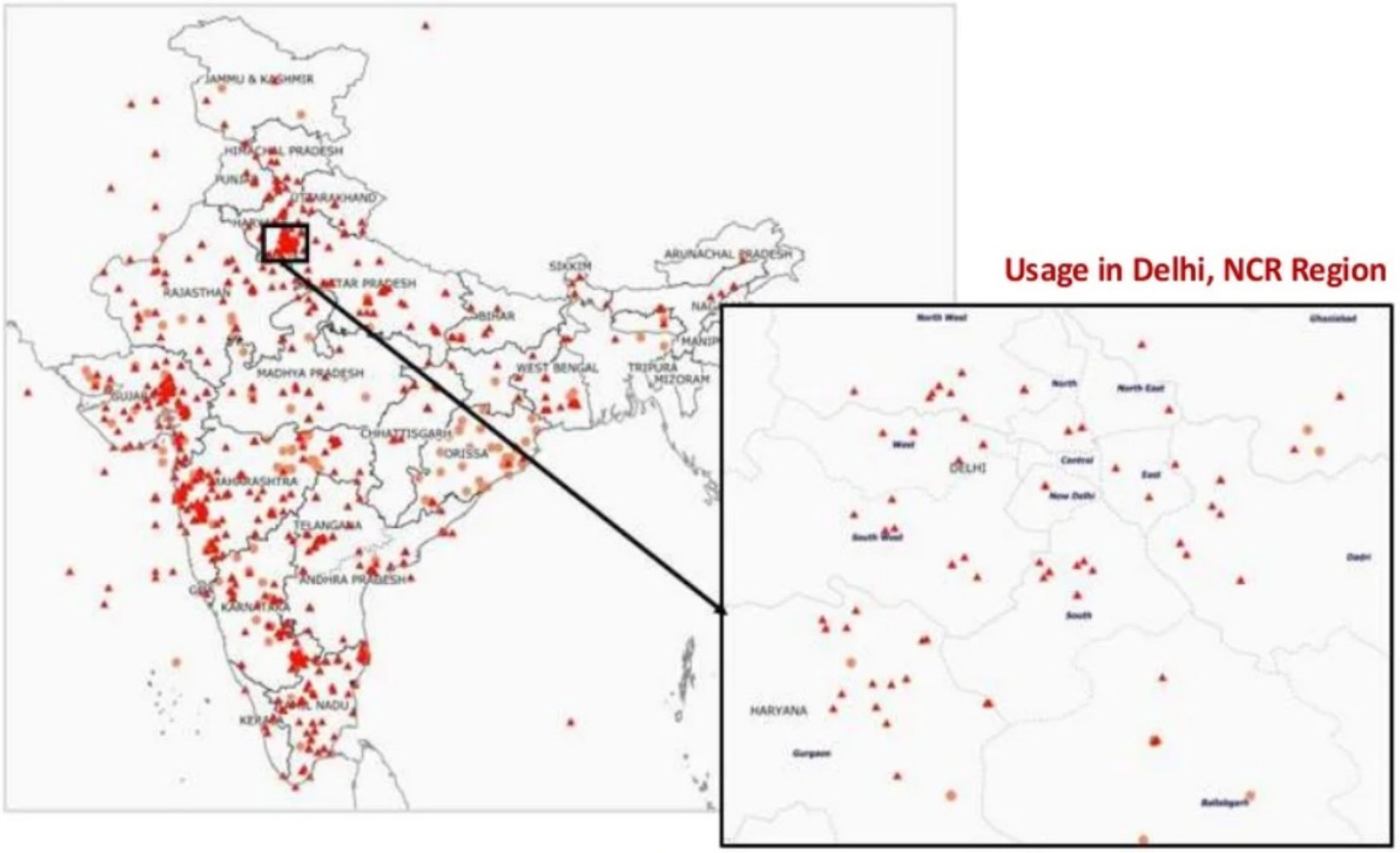


Image View



Visualisation of Earth Observation Data and Archival System
Beta

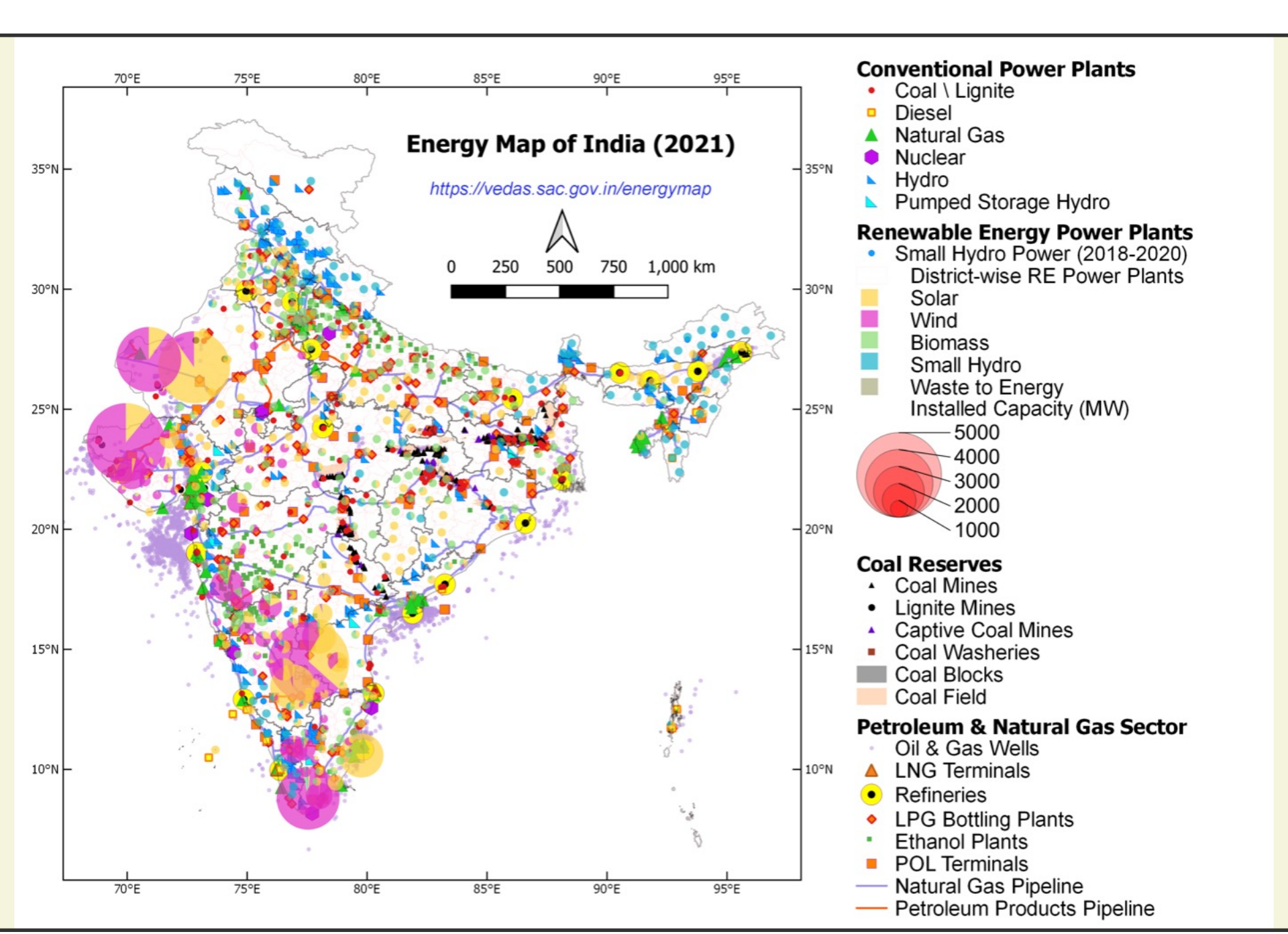
Usage of Solar Calculator

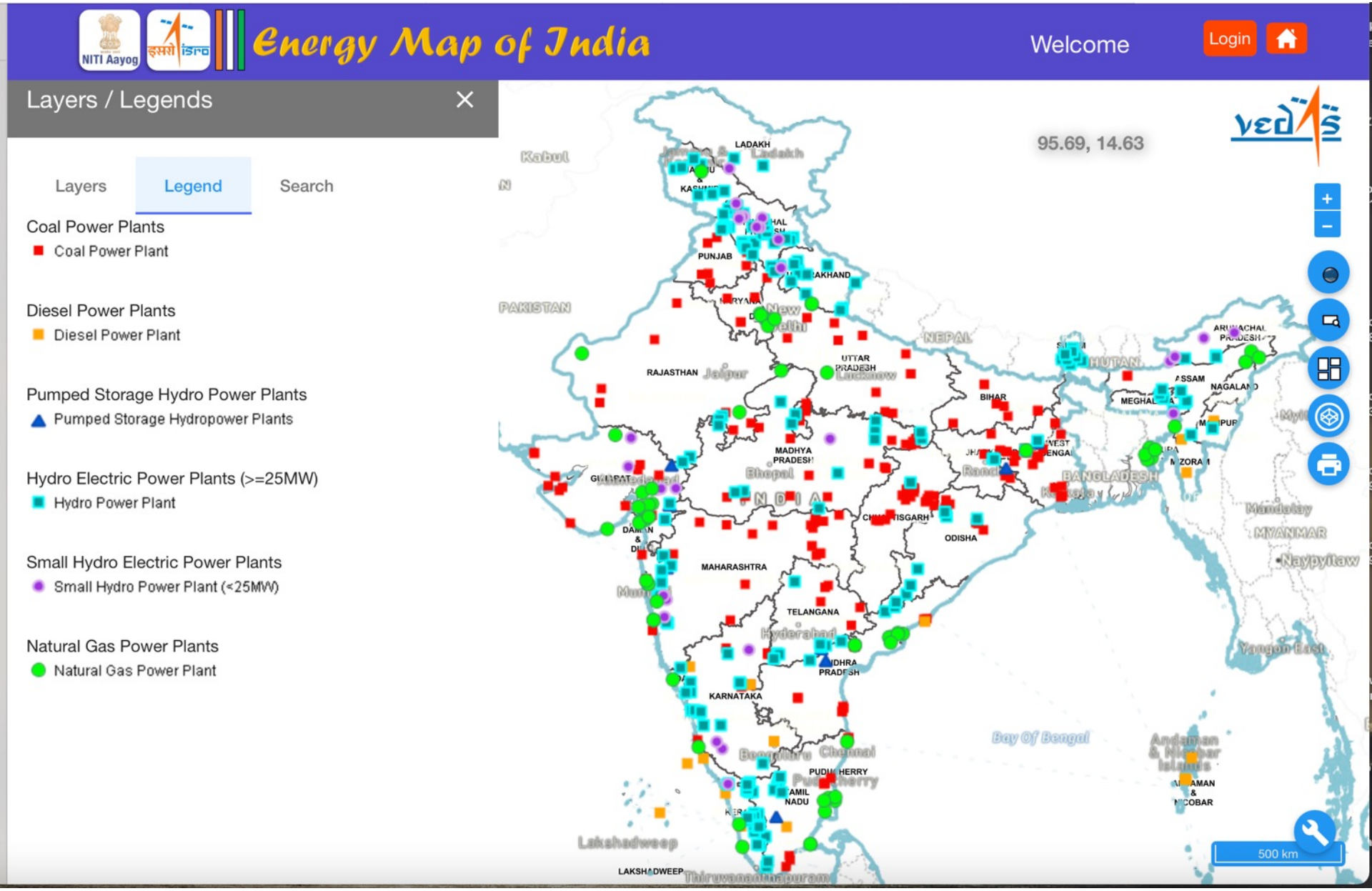


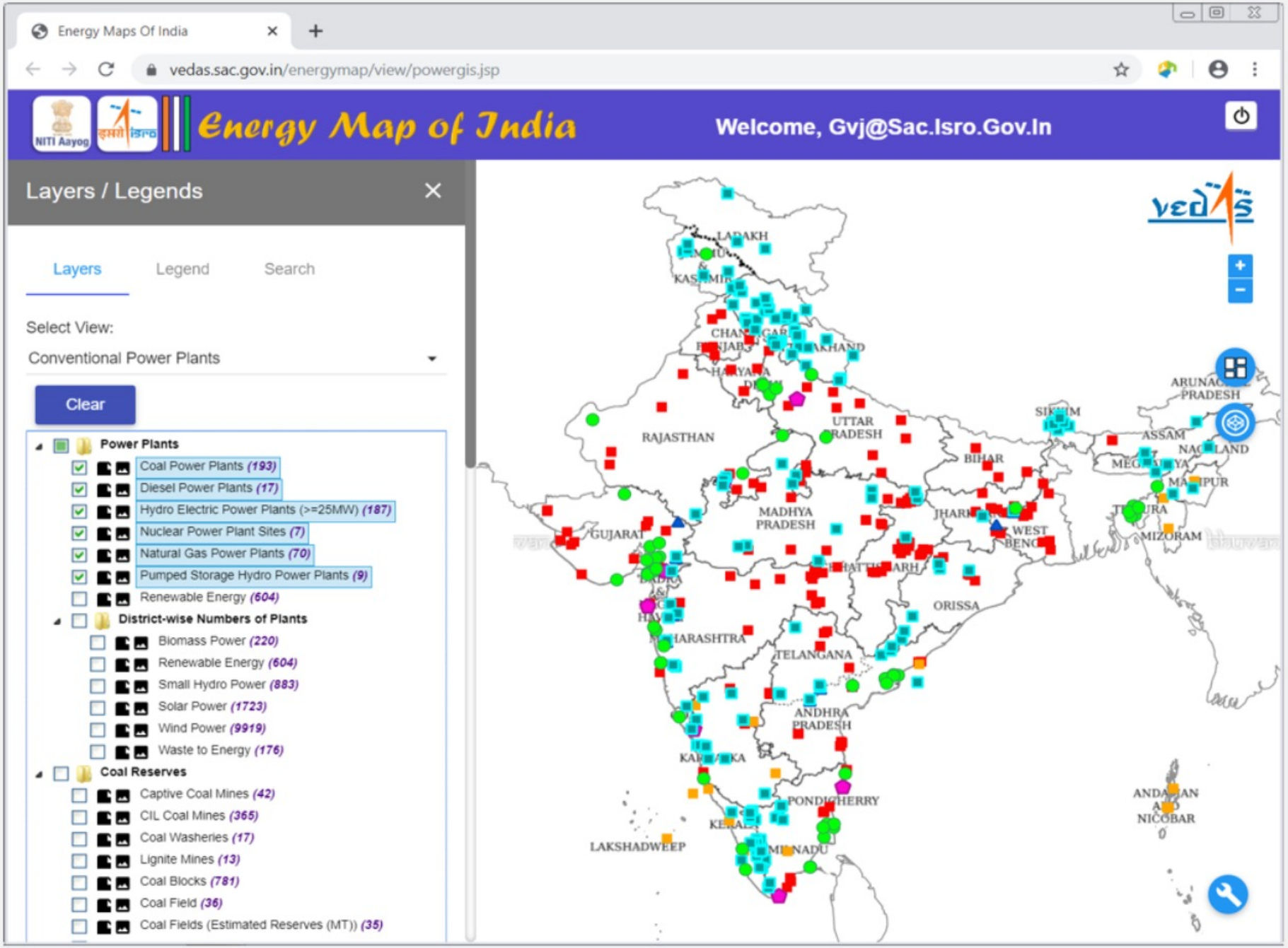
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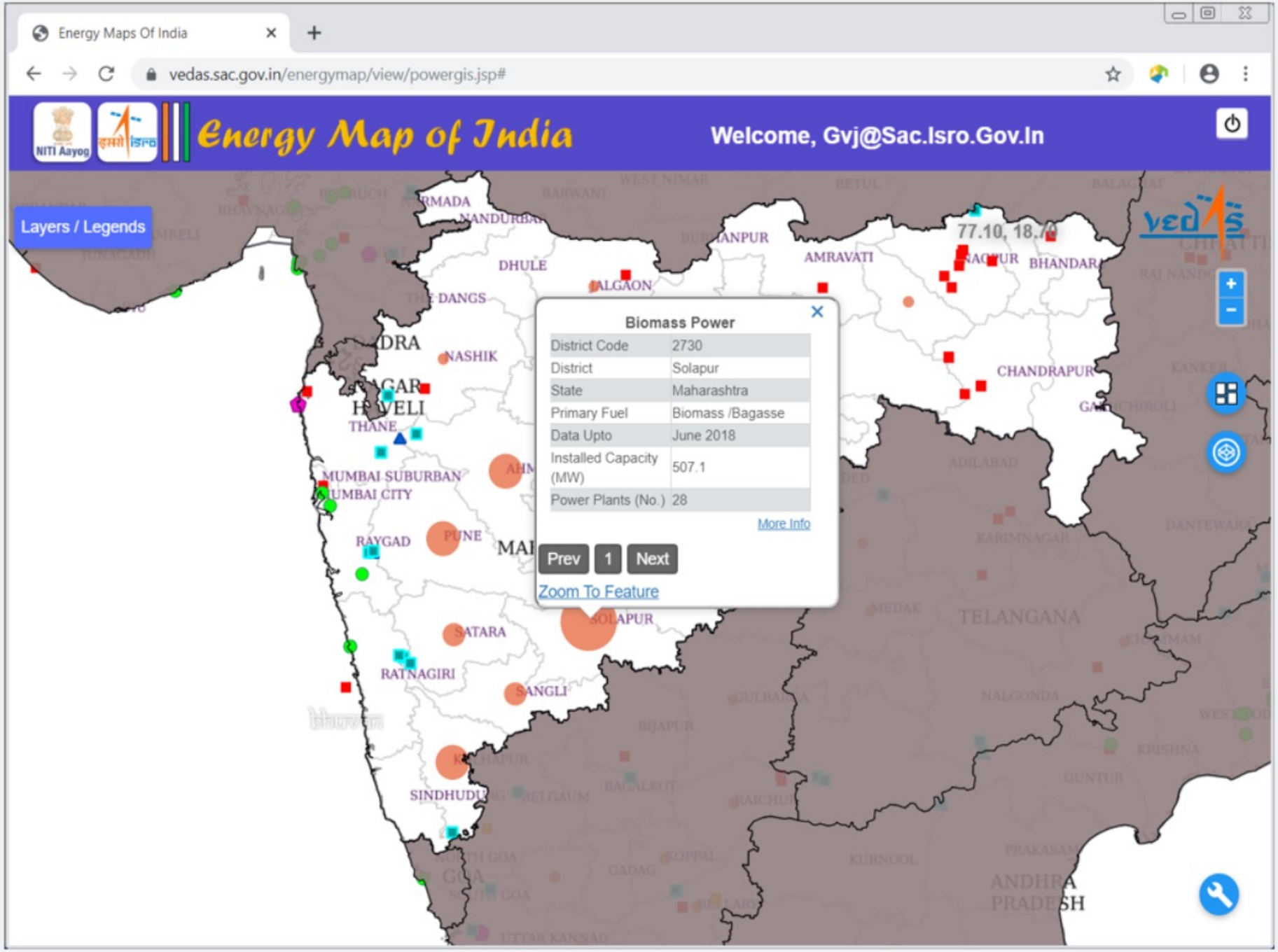
3D Building Model of Ahmedabad City Using Carosat-1 Stereo Pair




Energy Map of India (2021)
https://vedas.sac.gov.in/energymap
0 250 500 750 1,000 km
70°E
75°E
80°E
85°E
90°E
95°E
35°N
30°N
25°N
20°N
15°N
10°N
Conventional Power Plants
Coal \ Lignite
Diesel
Natural Gas
Nuclear
Hydro
Pumped Storage Hydro
Renewable Energy Power Plants
Small Hydro Power (2018-2020)
District-wise RE Power Plants
Solar
Wind
Biomass
Small Hydro
Waste to Energy
Installed Capacity (MW)
5000
4000
3000
2000
1000
Coal Reserves
Coal Mines
Lignite Mines
Captive Coal Mines
Coal Washeries
Coal Blocks
Coal Field
Petroleum & Natural Gas Sector
Oil & Gas Wells
LNG Terminals
Refineries
LPG Bottling Plants
Ethanol Plants
POL Terminals
Natural Gas Pipeline
Petroleum Products Pipeline


Energy Map of India
Welcome
Login
Layers / Legends
Layers
Legend
Search
Coal Power Plants
Coal Power Plant
Diesel Power Plants
Diesel Power Plant
Pumped Storage Hydro Power Plants
Pumped Storage Hydropower Plants
Hydro Electric Power Plants (>=25MW)
Hydro Power Plant
Small Hydro Electric Power Plants
Small Hydro Power Plant (<25MW)
Natural Gas Power Plants
Natural Gas Power Plant
95.69, 14.63
LADAKH
PUNJAB
PAKISTAN
NEPAL
RAJASTHAN
UTTAR PRADESH
BIHAR
MADHYA PRADESH
MAHARASHTRA
ODISHA
TELANGANA
KARNATAKA
BANGLADESH
MYANMAR
Bay Of Bengal
LAKSHADWEEP
500 km


Energy Maps Of India
vedas.sac.gov.in/energymap/view/powergis.jsp
Energy Map of India
Welcome, Gvj@Sac.Isro.Gov.In
Layers / Legends
Layers
Legend
Search
Select View:
Conventional Power Plants
Clear
Power Plants
Coal Power Plants (193)
Diesel Power Plants (17)
Hydro Electric Power Plants (>=25MW) (187)
Nuclear Power Plant Sites (7)
Natural Gas Power Plants (70)
Pumped Storage Hydro Power Plants (9)
Renewable Energy (604)
District-wise Numbers of Plants
Biomass Power (220)
Renewable Energy (604)
Small Hydro Power (883)
Solar Power (1723)
Wind Power (9919)
Waste to Energy (176)
Coal Reserves
Captive Coal Mines (42)
CIL Coal Mines (365)
Coal Washeries (17)
Lignite Mines (13)
Coal Blocks (781)
Coal Field (36)
Coal Fields (Estimated Reserves (MT)) (35)
LADAKH
RAJASTHAN
UTTAR PRADESH
BIHAR
SIKKIM
ASSAM
ARUNACHAL PRADESH
NAGALAND
MANIPUR
TRIPURA
MIZORAM
MADHYA PRADESH
JHARKHAND
WEST BENGAL
GUJARAT
ORISSA
MAHARASHTRA
TELANGANA
ANDHRA PRADESH
PONDICHERRY
LAKSHADWEEP
ANDAMAN AND NICOBAR


Energy Maps Of India
vedas.sac.gov.in/energymap/view/powergis.jsp#
Energy Map of India
Welcome, Gvj@Sac.Isro.Gov.In
Layers / Legends
Biomass Power
District Code 2730
District Solapur
State Maharashtra
Primary Fuel Biomass /Bagasse
Data Upto June 2018
Installed Capacity (MW) 507.1
Power Plants (No.) 28
More Info
Prev 1 Next
Zoom To Feature
77.10, 18.7
DHULE
JALGAON
AMRAVATI
BHANDARA
NASHIK
CHANDRAPUR
THANE
MUMBAI SUBURBAN
MUMBAI CITY
RAIGAD
PUNE
SOLAPUR
SATARA
RATNAGIRI
SANGLI
SINDHUDURG
TELANGANA
ANDHRA PRADESH

NITI Aayog launches Geospatial Energy Map of India in collaboration with ISRO



ThankYou