



#### Mapping the Future: Energizing Datadriven Policy Making and Investment in Renewable Energy

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

#### Outline

- Context for Geospatial Analysis
  - Geospatial Analysis Overview
  - Geospatial Analysis for Renewable Energy
- The Enterprise Geospatial Toolkit (EGsT)
  - EGsT Overview
    - Comparison to the Desktop GsT
    - Use Cases Overview
  - EGsT Current Capabilities
    - Big Data Downloads
    - Dynamic Technical Potential
    - CSTEP Site Selection
  - o EGsT Demo
  - EGsT Planned Development
    - Renewable Energy Zones (REZ) Support Tool
    - Economic Potential
    - Grid Integration Support Tool
    - Metadata Repository Integration
  - EGsT Country Expansion
- Presentations by CSTEP and NITI Aayog
- Hands-on Training on EGsT and Desktop GsT
- Group Discussion on Future Needs

## **Context for Geospatial Analysis**

#### **Geospatial Analysis**

Geospatial analysis provides a distinct perspective of the physical world, a unique lens through which to examine events, patterns, and processes that operate on or near the surface of our planet.



### **Geospatial Analysis**

- Basic Primitives
  - Place(s)
  - Attributes
  - Arrangement, Scale, Resolution
- Spatial Relationships
  - Power of location is derived from relative positions
- Spatial Statistics
  - Application of statistical methods to data with explicit spatial structure
  - Close association with traditional statistics and computational statistics
- Spatial Data Infrastructure
  - Set of representations created using recognized standards that provide sources of spatial data and tools



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Source: Geospatial Analysis – 5<sup>th</sup> Edition, 2015 – de Smith, Goodchild, Longley

Points, Lines and Polygons

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Power Plants

**Points** 

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#### Philippines Wind Resource Analysis

Shown: Regional Wind Speed





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Philippines Wind Resource Analysis

Shown: Regional Wind Speed with Sub-Optimal Resource Overlaid



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#### Philippines Wind Resource Analysis

Shown: Regional Wind Speed with Sub-Optimal Resource Removed Speed (m/s) > 10 9 - 9.5 8.5 - 9 8 - 8.5 7.5 - 8 7 - 7.5 6.5 - 7 6 - 6.5



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#### Philippines Wind Resource Analysis

Shown: Regional Wind Speed with Protected Areas Overlaid





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#### Philippines Wind Resource Analysis

Shown: Regional Wind Speed with Transmission and Roads Overlaid and Remote Areas Overlaid Speed (m/s) > 10 9 - 9.5 8.5 - 9 8 - 8.5 7.5 - 8 7 - 7.5 6.5 - 7 6 - 6.5



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#### Linear Scaling Wind Profiles







Actual Year data has hourly and daily variability that corresponds to load, however, is of poor spatial resolution.



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#### Gaussian filter with 8 standard deviations applied with two moving windows (24-48 hours) normalizing and then applying a linear scaling.



#### Results show preservation of temporal variability, distribution, and area under the curve

10 15 20 Wind speed (m/s)





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Observations of latitude, longitude, temperature, and depth.







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Temperature at depth maps resulting from kriging.







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Estimated Temperature at Depth (°C)

25 50 75 100 125 150 250

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#### Estimating Shallow, Low-Temperature Geothermal Resources



28

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#### • Where do we start?



## Enterprise Geospatial Toolkit (EGsT)

### First, What is the Desktop Geospatial Toolkit?

- Stand-alone desktop GIS software application
- Combines renewable resource information with other cadastral, environmental, and infrastructure data
- Explores data visually and with targeted, quantitative geospatial analysis functionality
- Free and open-source tool
- No GIS expertise required



### Now... What is the Enterprise Geospatial Toolkit (EGsT)?

- Possess all the same qualities as the desktop GsT
- In addition...
  - Web-based GIS system
  - Integration with hourly and sub-hourly resource data
  - Advanced spatial analysis continually being developed
  - Security and authorization
  - Printable maps & reports
  - Downloadable map & legend images



#### EGsT Architecture

- Web client built on EmberJS framework using Leaflet, D3, and Highcharts for data visualization
- Map tile servers utilize Geoserver
- Analysis APIs utilize Ruby on Rails endpoints to call PostGIS or Python analysis processes
- Data stored as PostgreSQL/PostGIS tables, HDF5 files, and rasters
- Code management through Git/GitHub
- Enterprise GsT utilizes Amazon Web Services to host data and analysis scripts



#### **EGsT Data**

#### Renewable resource data

- Gridded solar and wind resource data
- Biomass, geothermal, hydro, and conventional resources can also be added

#### • Base data

- Elevation and slope
- Land use/land cover
- Protected areas
- Political boundaries
- Cities/towns
- Rivers and lakes
- Infrastructure data
  - o Transmission lines
  - Roads and railroads
  - Power plants
- Other data of interest (examples)
  - Meteorological stations
  - Rural development priorities (schools, clinics, etc)



### EGsT Use-Case(s)

- Estimate RE potential to inform targets
- Identify tradeoffs and synergies between sustainable land use and clean energy
- Estimate generation costs to inform subsidies
- Identify areas where RE supports development priorities (e.g., electrification, climate resiliency, energy security)
- Screen for potential RE development zones (national and regional)
- Screen for potential development sites
- Identify sites for long-term measurement stations
- Access solar and wind time-series data for grid integration analysis, prefeasibility assessment, or system design
- One stop for relevant geospatial and spatiotemporal data for renewable energy



\* Data and Analysis Various by Country/Region

## **EGsT Current Capabilities**

#### **Big Data Downloads**

- Allows users to download a pixel or region of hourly solar or 5-minute wind\* resource including ancillary meteorological data
- Provides access to 10's of terabytes of wind and solar resource data



### **Big Data Downloads**

#### Users

- Electric utility consultants
- Utility planners
- Academics
- Project Developers
- Energy Analysts
- Technology Engineers

#### Use Cases

- Site based generator energy estimates
- Generator exceedance
   probabilities
- Generator financial modeling
- Base data for grid integration analysis
  - Production cost models
  - Capacity expansion models

#### **Technical Potential**

 Dynamically conduct user specified technical potential at the regional or country level

Select and Que

Laos Resource Use the Resource resource potentia

Use the Resource resource potenti Myanmar Re Use the Resource resource potenti

Thailand Res Use the Resource resource potentia

 Allows stakeholders to evaluate impacts of various barriers to renewable energy deployment

Inputs       Results         National Results       Regional/State Results         DC Generation:       60.1 MWh/yr         Total Land Area:       2013.5 km <sup>2</sup> Nameplate       96648.1 MW         Capacity:       Wind Resource Bounds         Minimum:       196.0 W/m <sup>2</sup> Maximum:       392.0 W/m <sup>2</sup> 206 266 W/m <sup>2</sup> 307 km <sup>2</sup> 206 266 W/m <sup>2</sup> 305 km <sup>2</sup> 207 207 W/m <sup>2</sup> 338 km <sup>2</sup> 207 207 W/m <sup>2</sup> 334 km <sup>2</sup> 207 207 W/m <sup>2</sup> 334 km <sup>2</sup> 207 207 W/m <sup>2</sup> 334 km <sup>2</sup> 207 207 W/m <sup>2</sup> 344 km <sup>2</sup> 208 208 W/m <sup>2</sup> 344 km <sup>2</sup> 208 208 W/m <sup>2</sup> 15 km <sup>2</sup> 208 208 W/m <sup>2</sup> 16 km <sup>2</sup> Windt       W/m <sup>2</sup> Base       W/m <sup>2</sup> Base       W/m <sup>2</sup> Base       W/m <sup>2</sup> Windt       W/m <sup>2</sup> Windt       W/m <sup>2</sup> Windt					
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### **Technical Potential**

#### Users

- Transmission developers
- Regional organizations
- NGO's
- Project developers
- State offices
- Energy Analysts

#### Use Cases

- Policy analysis evaluation of barriers and impacts to RE targets
- Base data for grid integration analysis
  - Production cost models
  - Capacity expansion models
- Land use and environmental impact analysis
- Utility-scale site identification

## EGsT Live Demo

## Planned Development

#### Renewable Energy Zone Support Tool

 Allow users to visualize, download, and interact with the zones identified by stakeholders in the REZ analysis framework



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#### Renewable Energy Zone Support Tool

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#### **Economic Potential**

- Assess the economic viability of different renewable energy technologies at a high geospatial resolution
- Specify scenarios to analyze the impact of incentive schemes or barriers to renewable energy deployment
- Aggregate results by national, state, or substate level





 Allow users to generate substationbased RE supply curves with associated class-based timeseries power profiles through a combination of dynamic technical potential and generator energy modeling

Substation











### Metadata Repository Integration

Sustainable Working G

 A robust search mechanism for users to find relevant data and load that data within the Enterprise GsT for visualization, querying, exploration, and downloading

eospatial	
S	Search Your Data
eg. solar, wind, tr	transportation, etc.
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## EGsT Country Expansion

#### **EGsT Existing Countries and Capabilities**

### • India (TDB)

- Dynamic Technical Potential
- Big Data Downloads
  - Solar, Wind Planned
- CSTEP Site Selection Tool

#### Lower Mekong

Dynamic Technical Potential

#### Philippines

Big Data Downloads

- Wind

Dynamic Technical Potential – Planned

#### **EGsT Planned Countries and Capabilities**

#### Bangladesh

• Dynamic Technical Potential

#### Indonesia

- Dynamic Technical Potential
- Kenya
  - Dynamic Technical Potential

#### Mexico

- Dynamic Technical Potential
- Big Data Downloads (wind, solar)

#### Guatemala

- Dynamic Technical Potential
- Big Data Downloads (wind, solar)

#### Nepal

- Dynamic Technical Potential
- Big Data Downloads (wind, solar)

#### Afghanistan

• Dynamic Technical Potential

#### Pakistan

Dynamic Technical Potential

## **CSTEP and NITI Aayog Presentations**

## Hands-on Training

### Hands-on Training

**EGsT** Countries

- Lower Mekong maps.nrel.gov/gst-lower-mekong
- **Philippines** maps.nrel.gov/gstphilippines

#### Desktop GsT Countries

- Afghanistan
- Bangladesh
- Bhutan
- Cambodia
- China (Hebei)
- India
- Indonesia
- Malaysia
- Nepal
- Pakistan
- Philippines
- Sri Lanka
- Thailand
- Vietnam
- Vietnam (Thanh Hoa)

#### http://www.nrel.gov/international/geospatial\_toolkits.html

### Hands-on Training

- Identify *the clean energy question* you want to explore
- Identify *analysis considerations* to frame the question in terms of GsT data layers and query parameters
- Explore the data layers *visually* to see the data distribution of important layers and to gain a general impression of major opportunities and constraints
- Decide initial *filtering criteria*, starting with a few criteria determined most impactful
- Conduct *quantitative analysis* where possible using the technical potential functionality
- Review results and decide whether further refinement is needed through sensitivity analysis
- Understand *limitations* of the GsT analysis and where additional tools or information could supplement and improve upon this analysis

maps.nrel.gov/gst-lower-mekong

maps.nrel.gov/gst-philippines

NATIONAL RENEWABLE ENERGY LABORATORY

## **Group Discussion**

#### Thank You

#### **Technical Questions and Troubleshooting**

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#### **Information About EC-LEDS GsT Activities**

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Resources:

- Geospatial Toolkit downloads: <u>http://www.nrel.gov/international/geospatial\_toolkits</u> .html
- Enhancing Capacity for Low Emission Development Strategies: www.ec-leds.org

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#### www.nrel.gov



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