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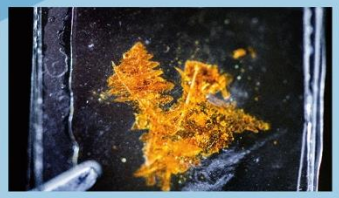
NATIONAL RENEWABLE ENERGY LABORATORY




Mapping the Future: *Energizing Data-driven Policy Making and Investment in Renewable Energy*

Anthony Lopez

Manager – Geospatial Data Science

National Renewable Energy Laboratory

June 6, 2016

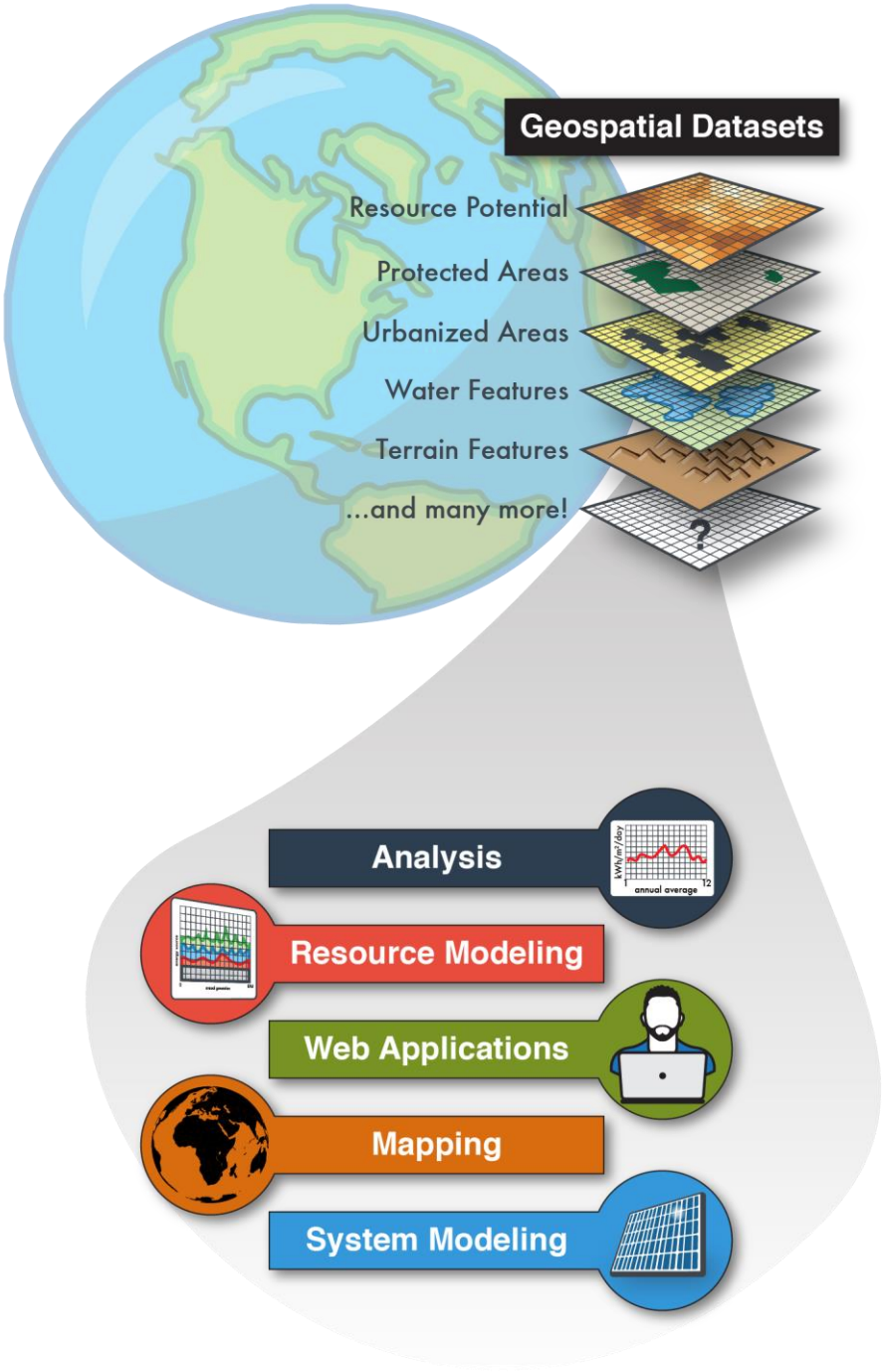
Outline

- 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
  - 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.



Source: Geospatial Analysis – 5th Edition, 2015 – de Smith, Goodchild, Longley

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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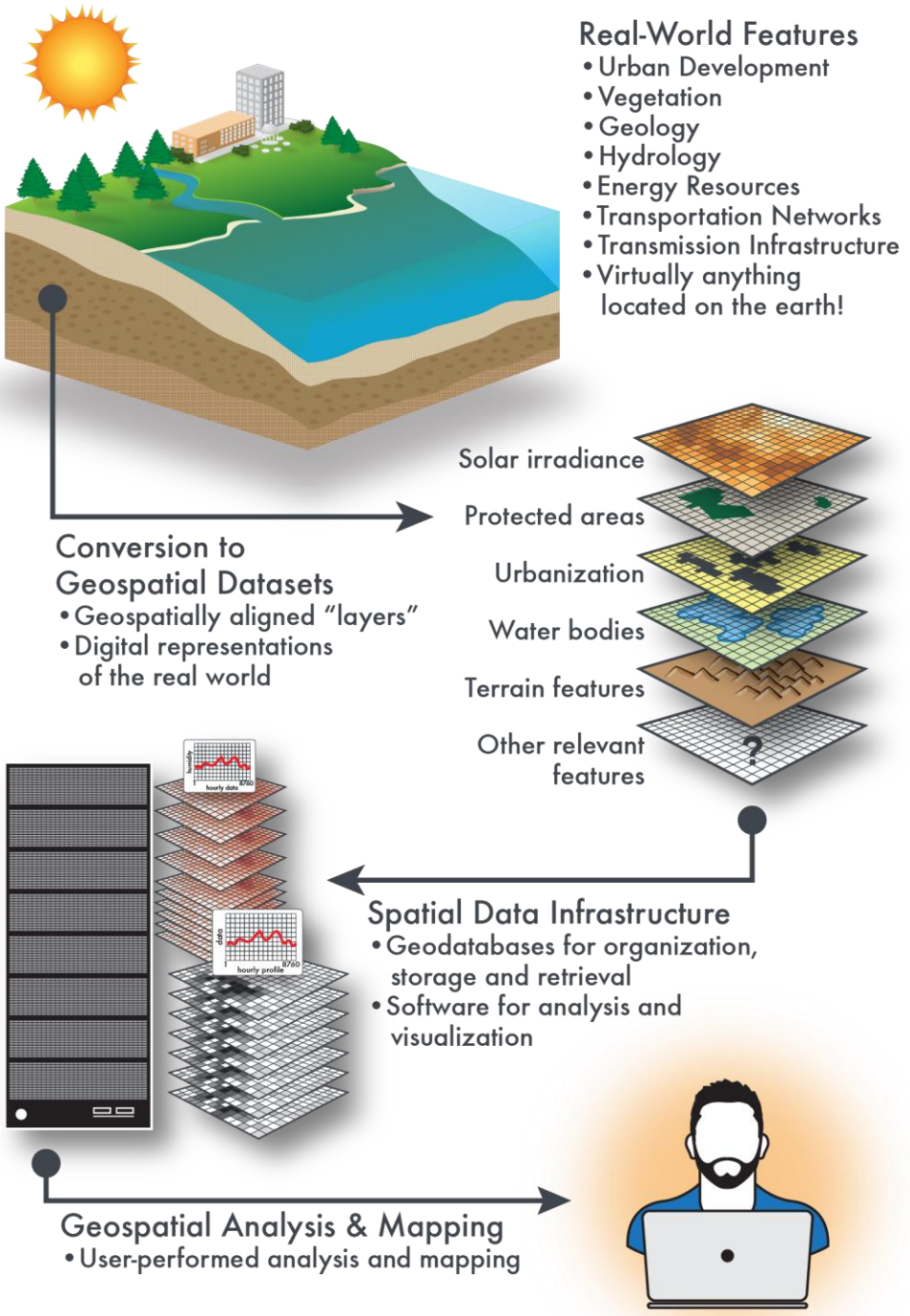

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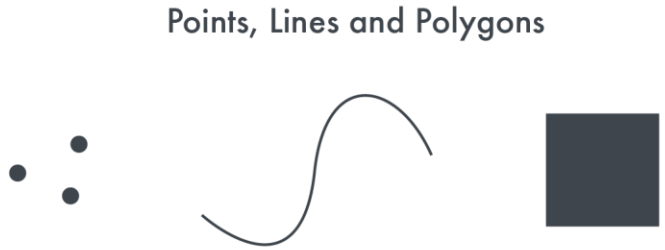

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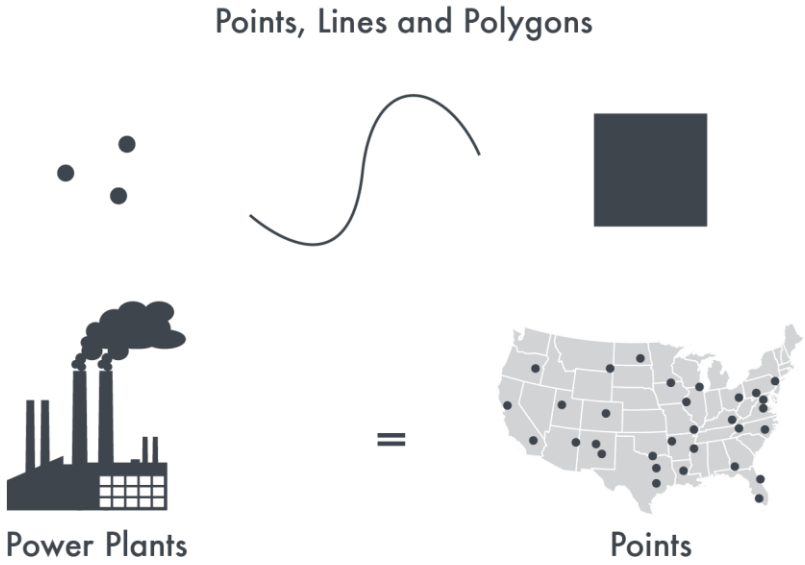

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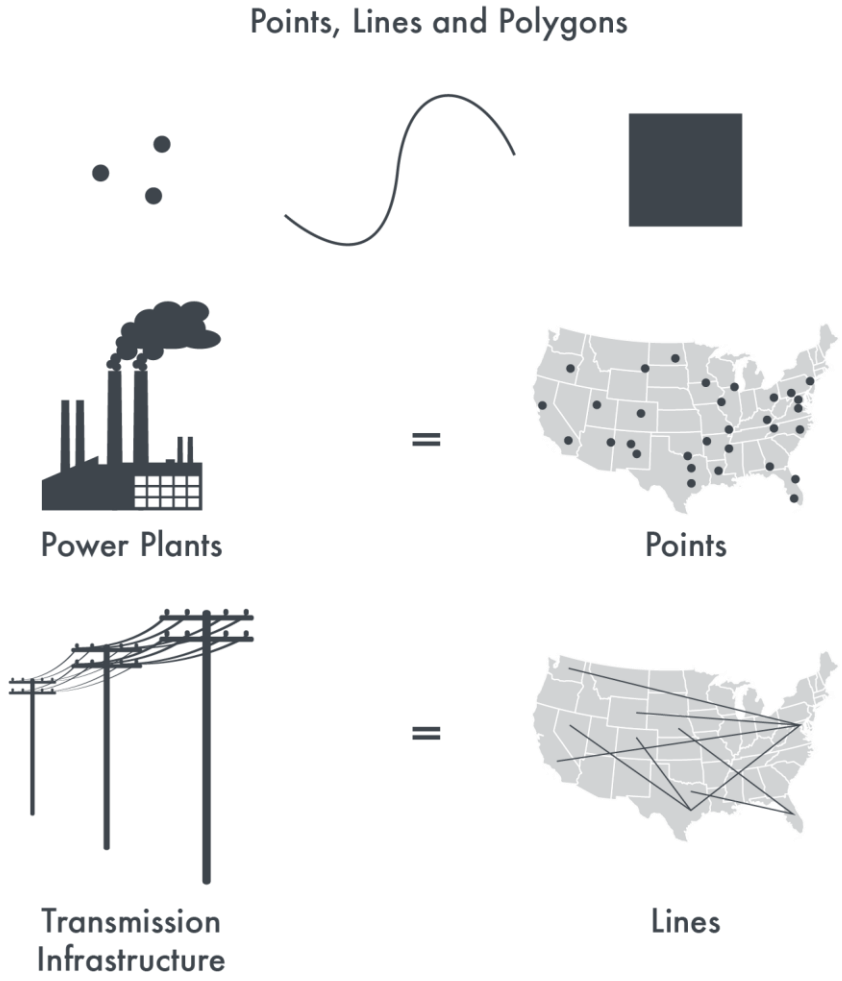

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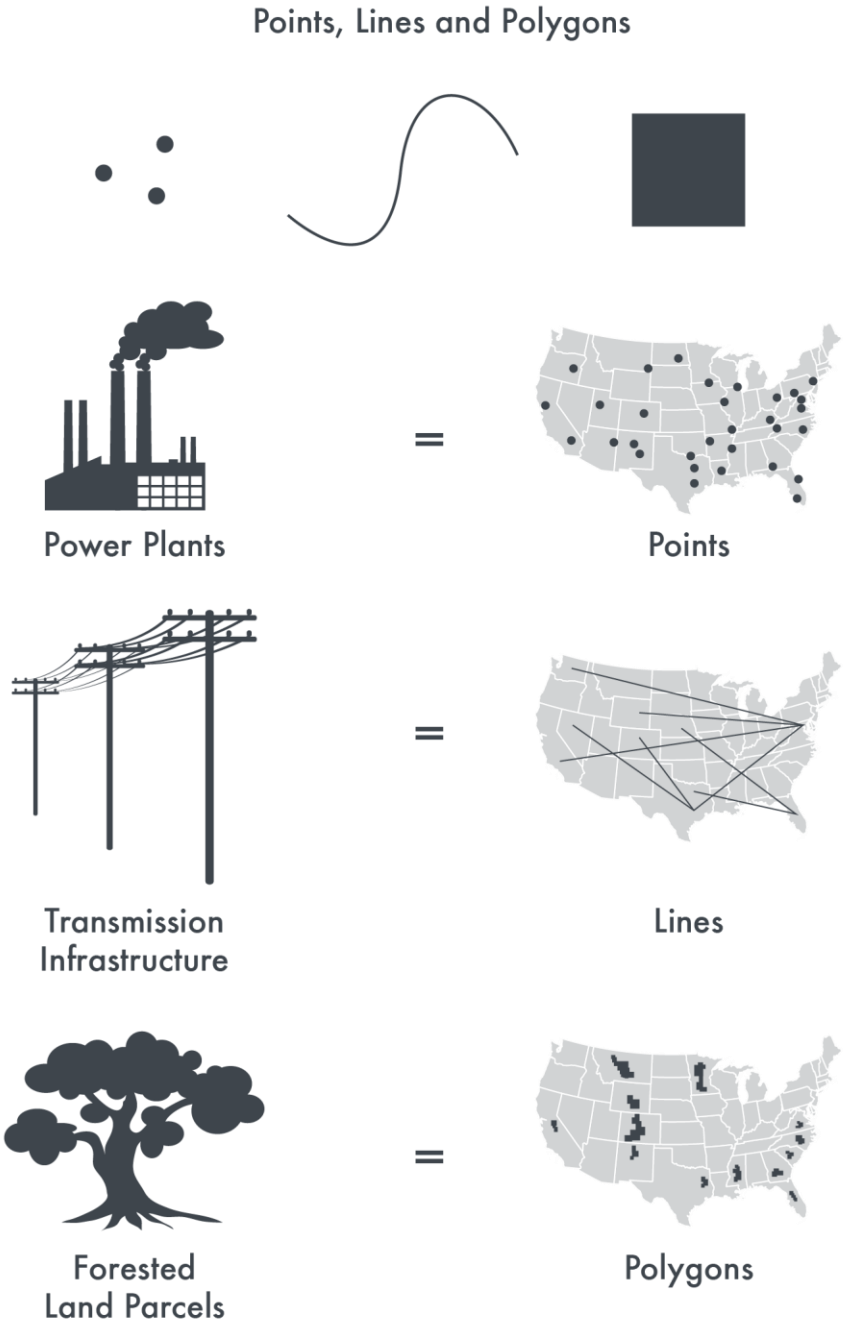

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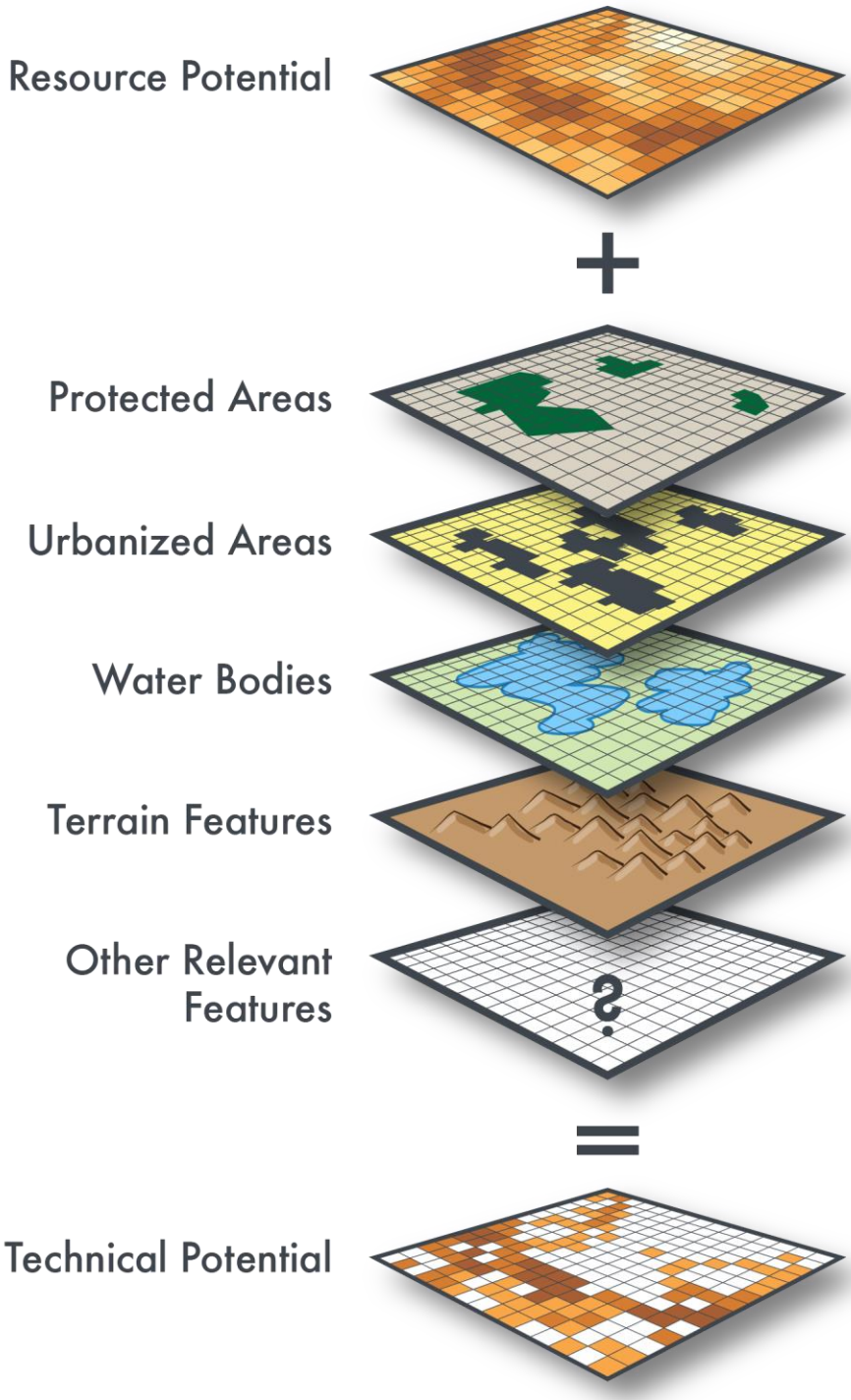

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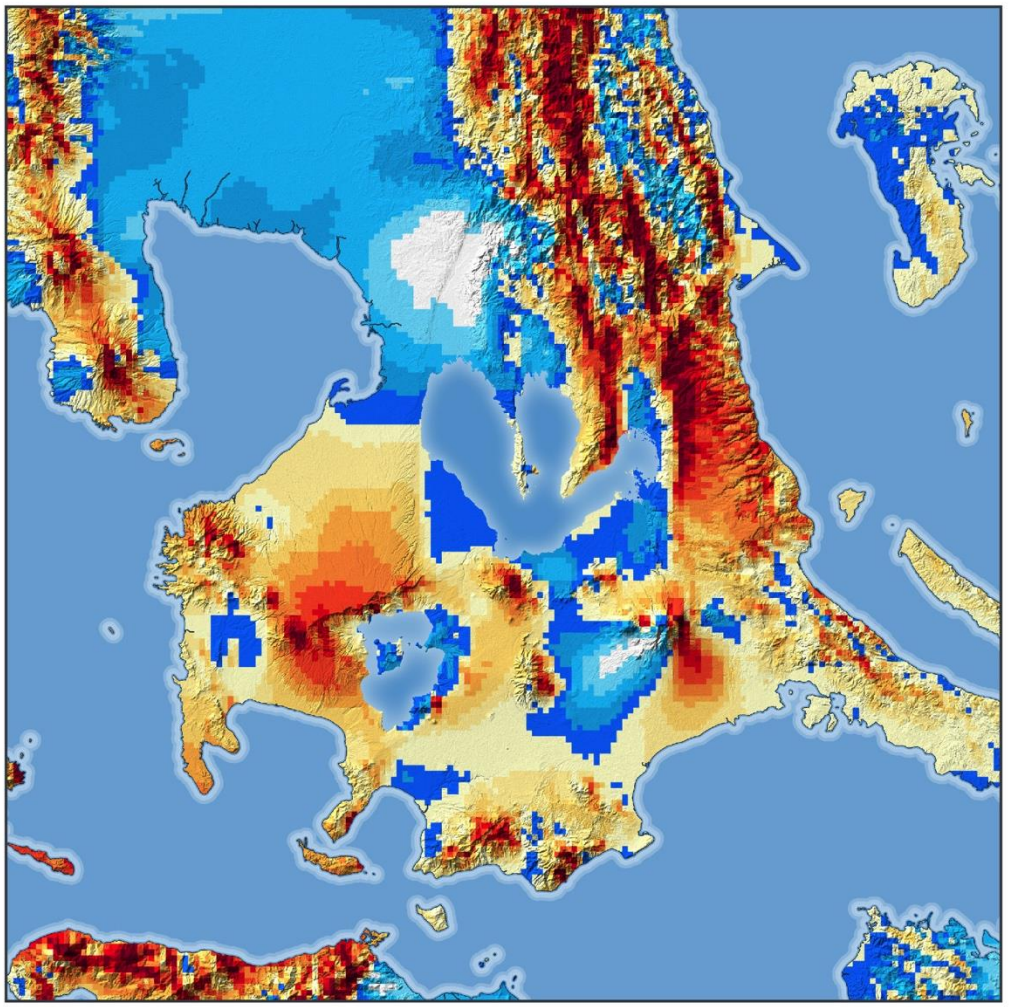
Philippines Wind Resource Analysis

Shown:
Regional Wind Speed



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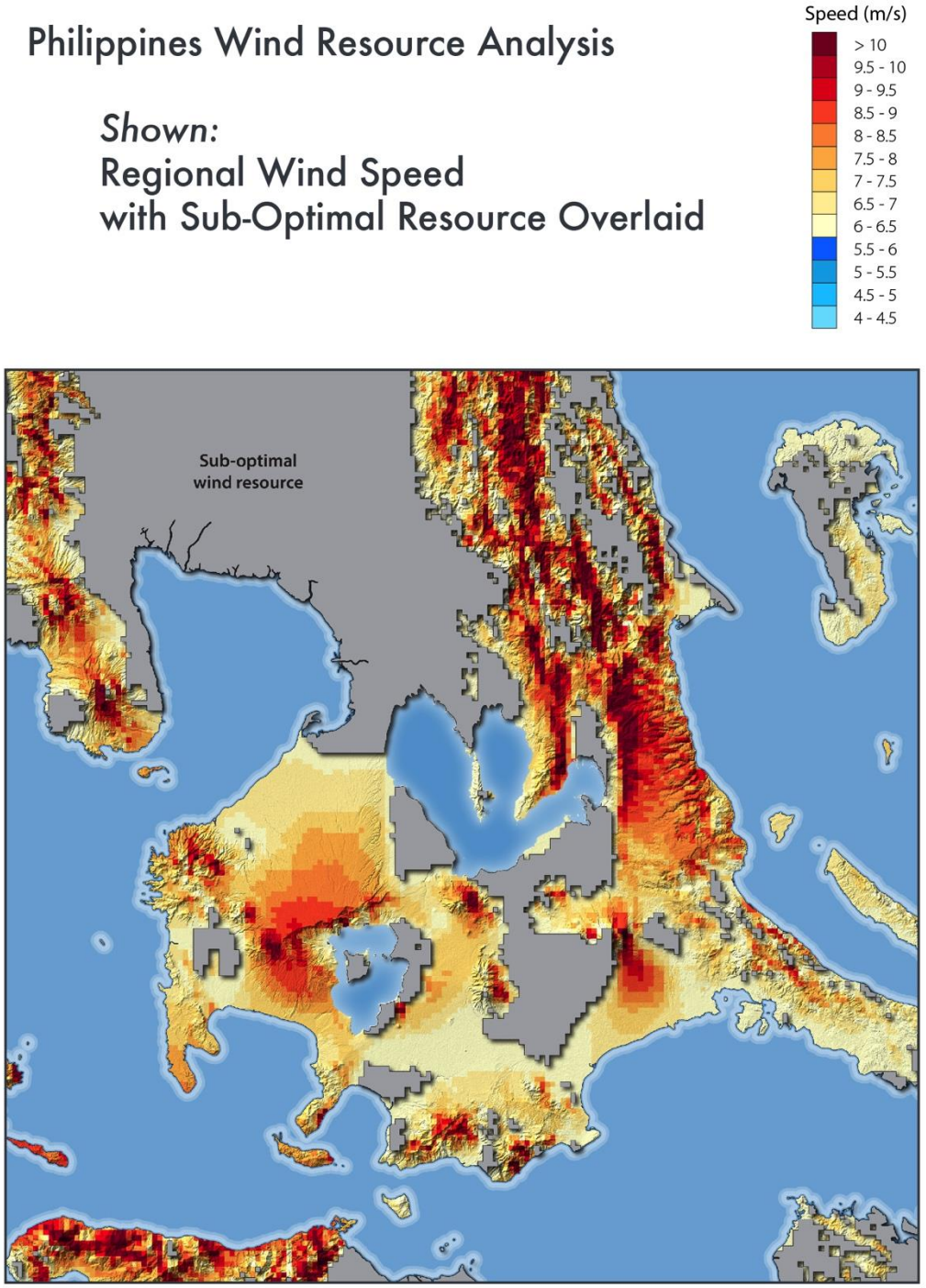
Philippines Wind Resource Analysis

Shown:
Regional Wind Speed
with Sub-Optimal Resource Overlaid



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Regional Wind Speed
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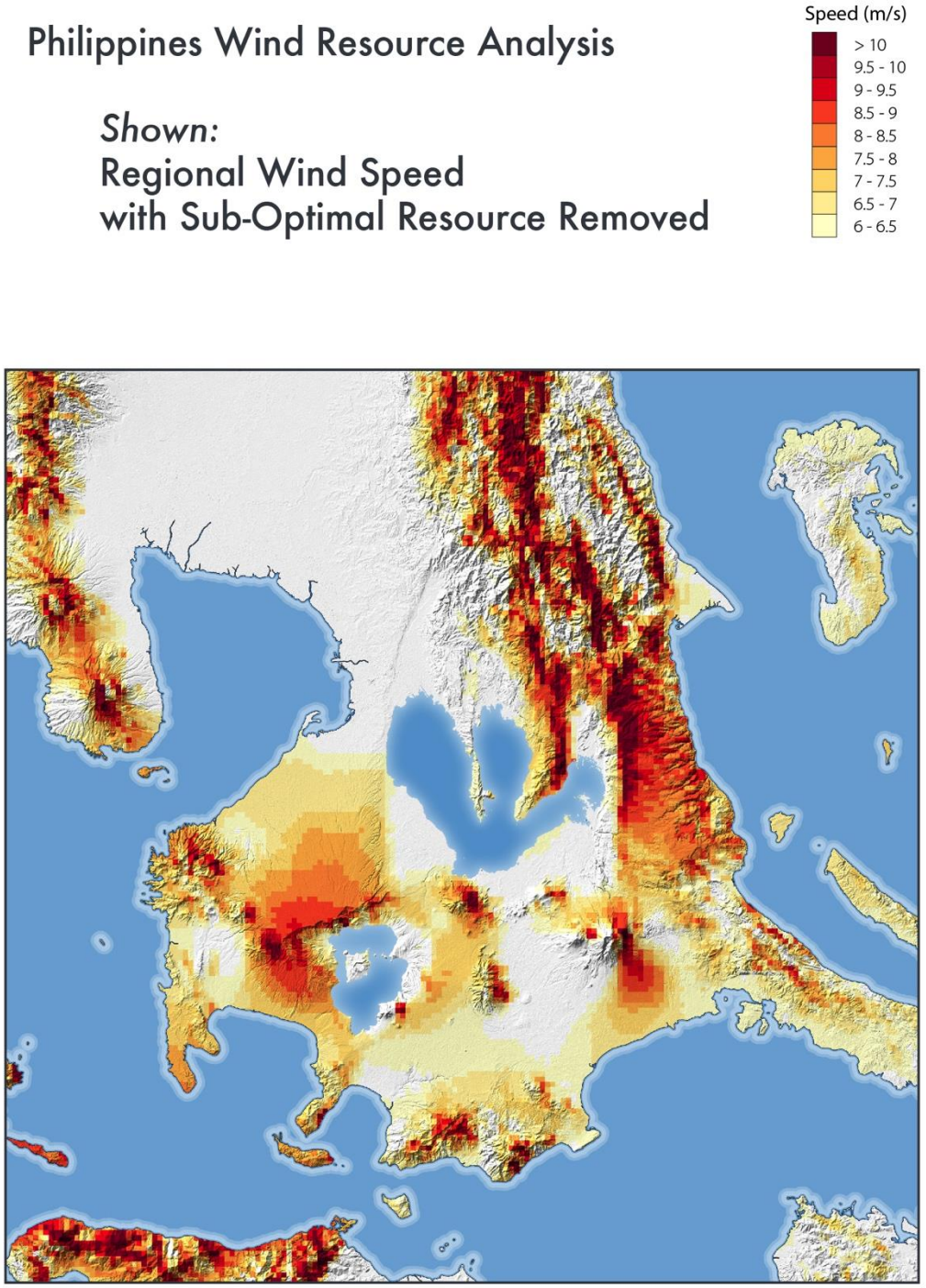

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Regional Wind Speed
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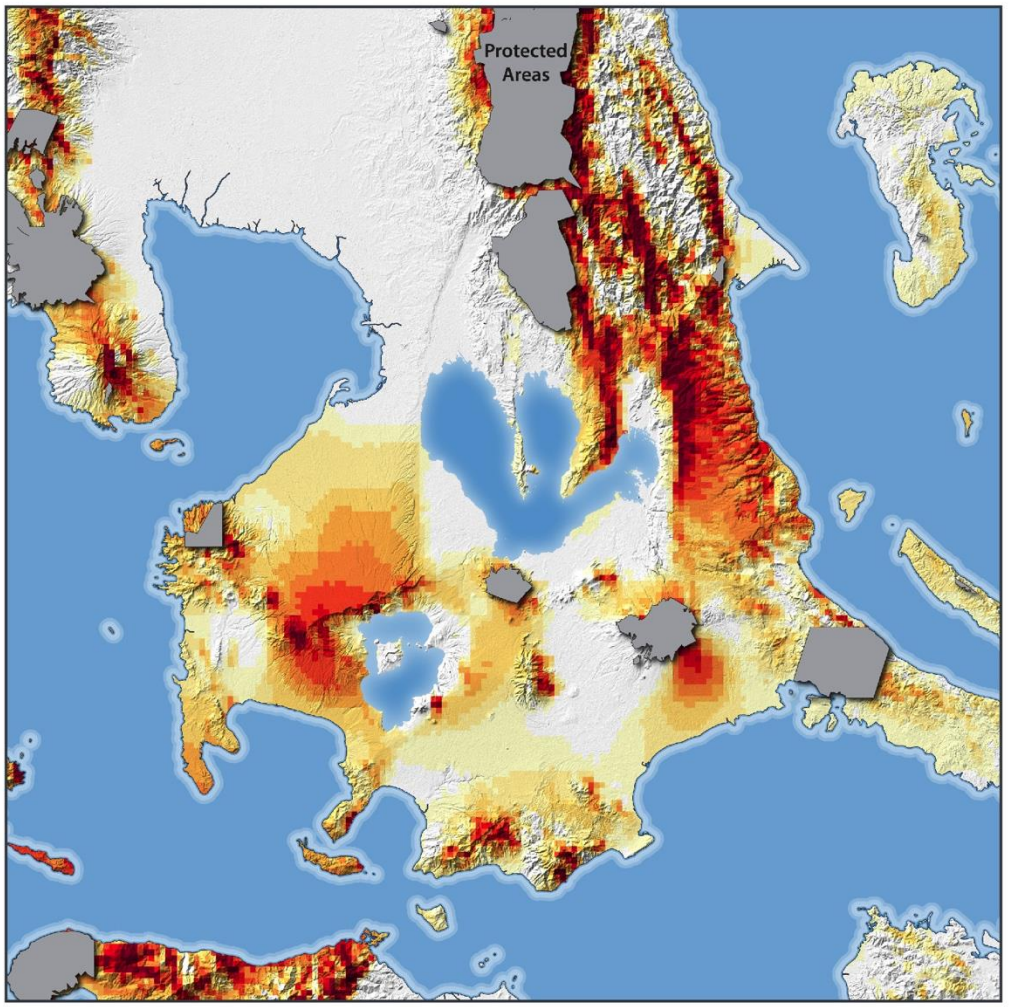

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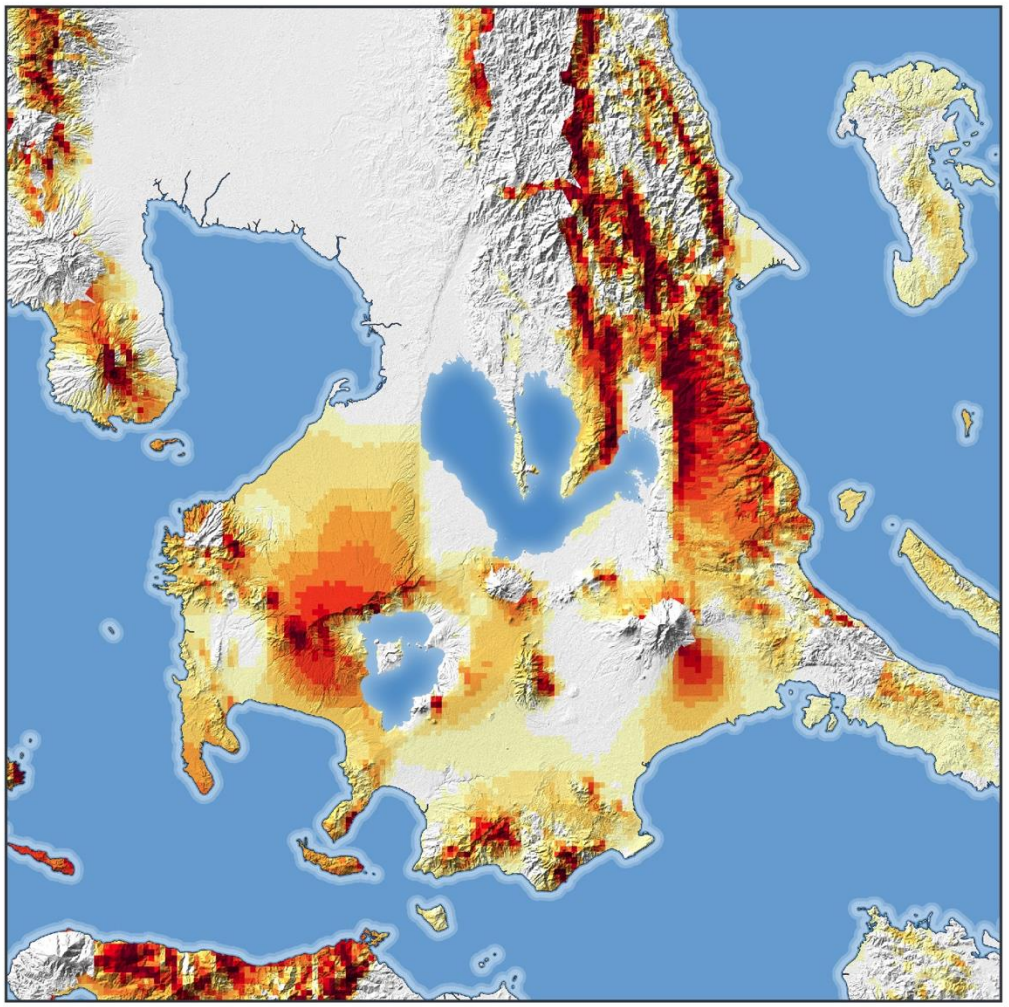

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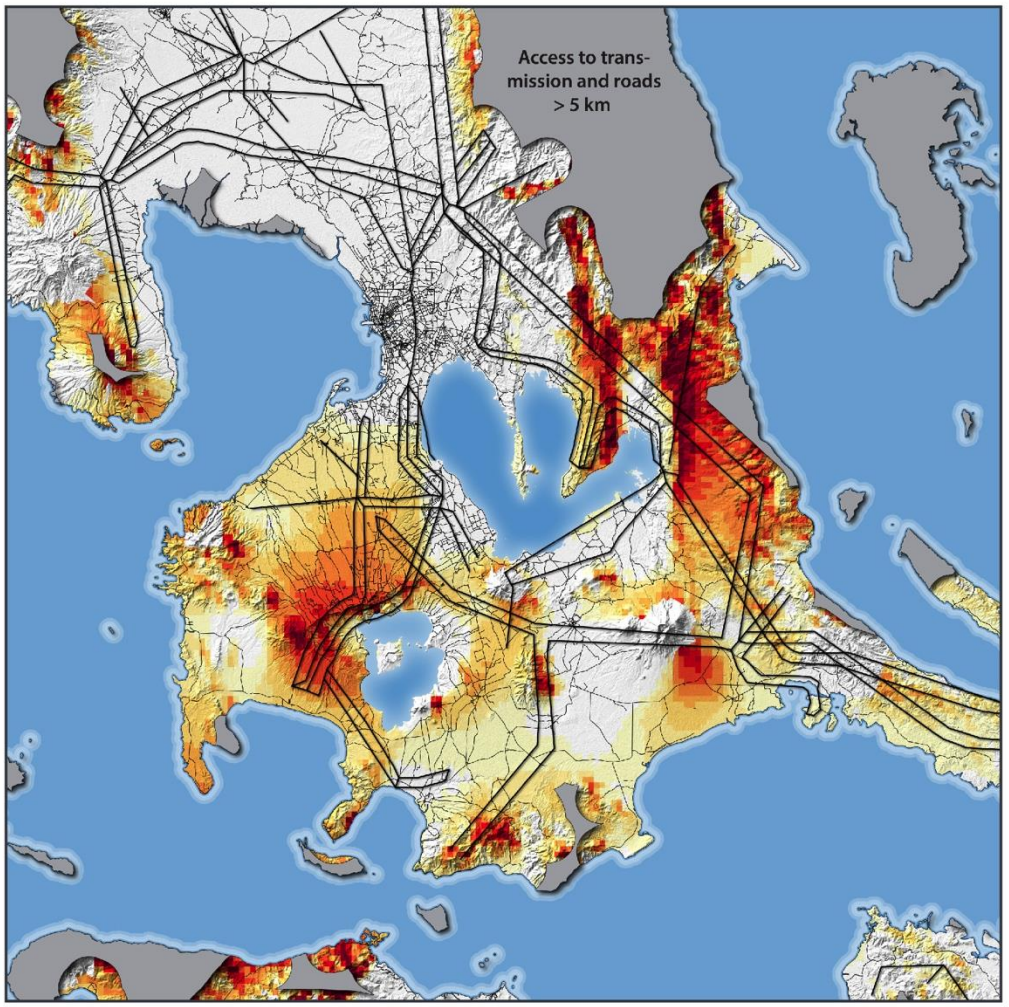
Regional Wind Speed
with Transmission and Roads Overlaid
and Remote Areas Overlaid



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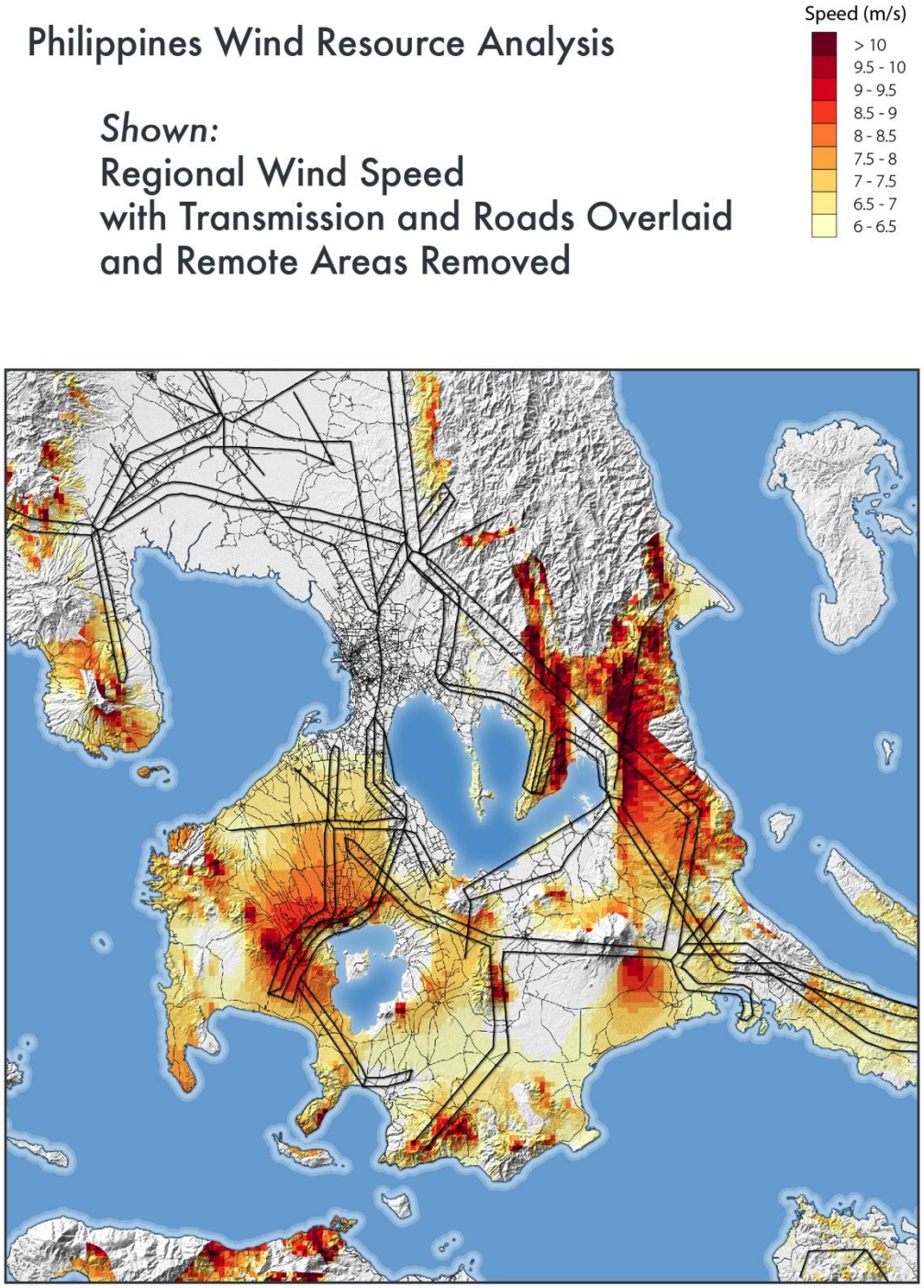

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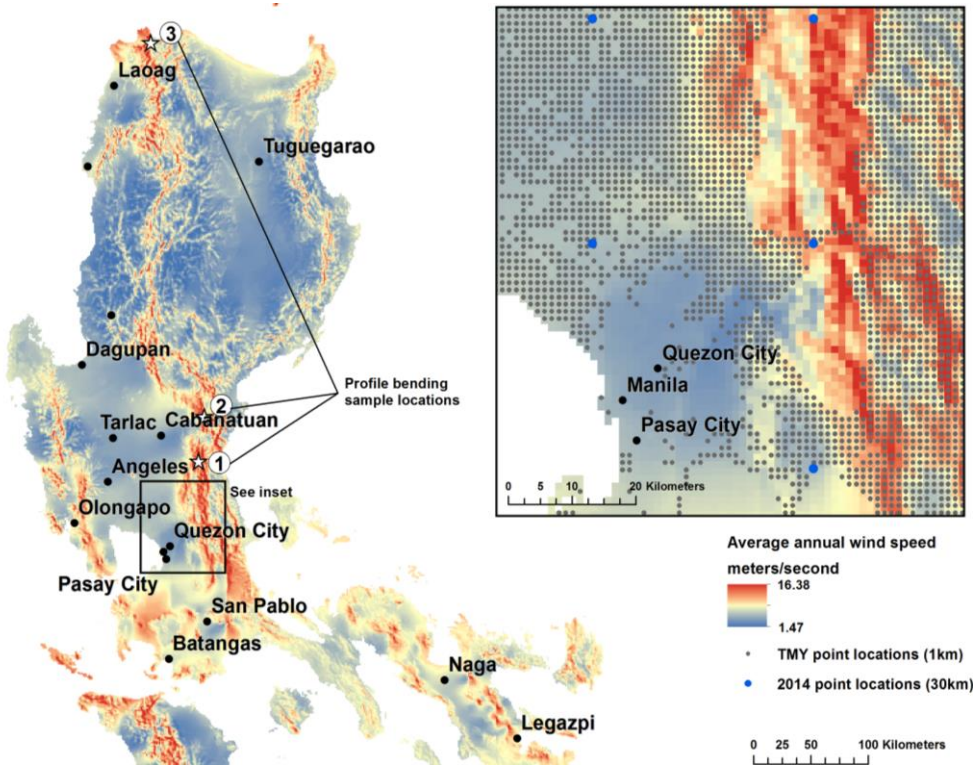
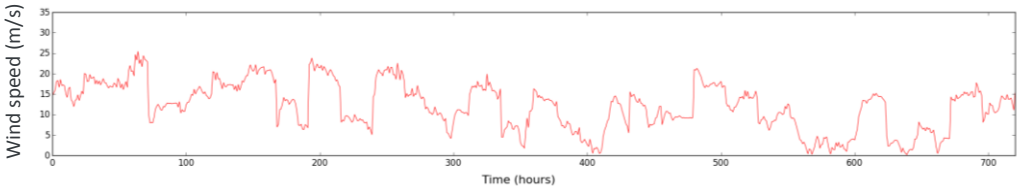
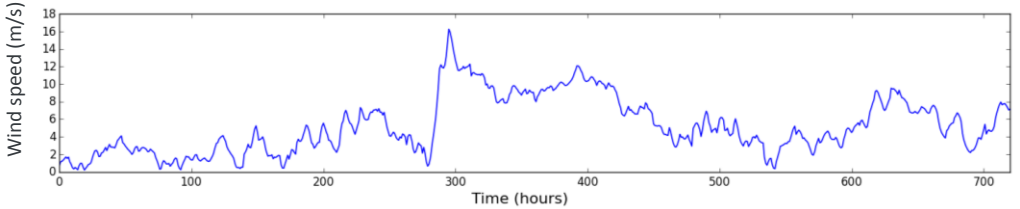
Linear Scaling Wind Profiles



Typical Meteorological Year (TMY) informs expected generation but lacks coincidence with load time-series required for grid integration.



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



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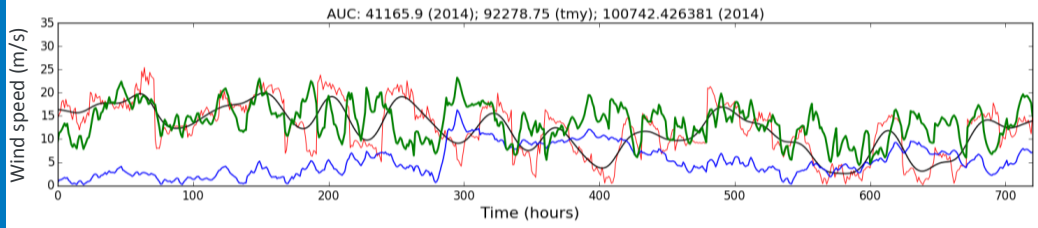
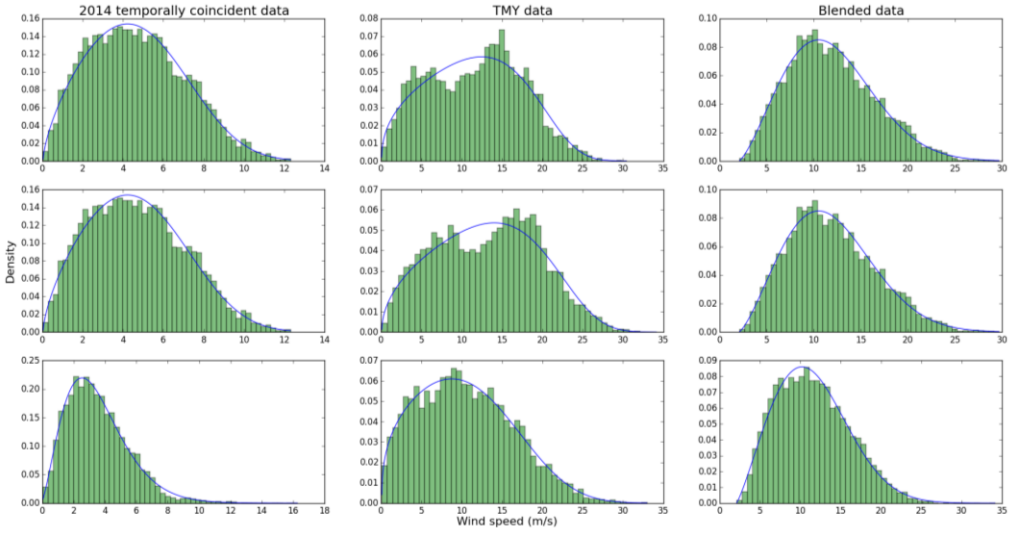
Linear Scaling Wind Profiles

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



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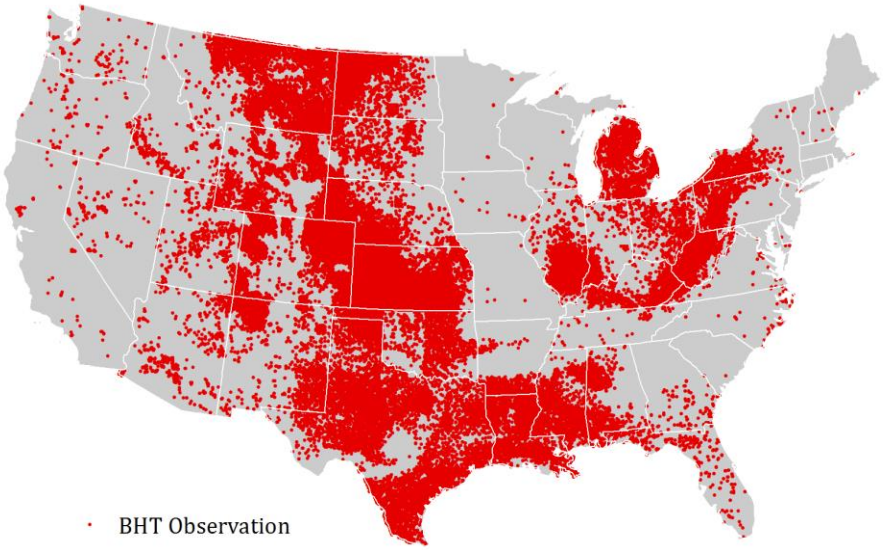
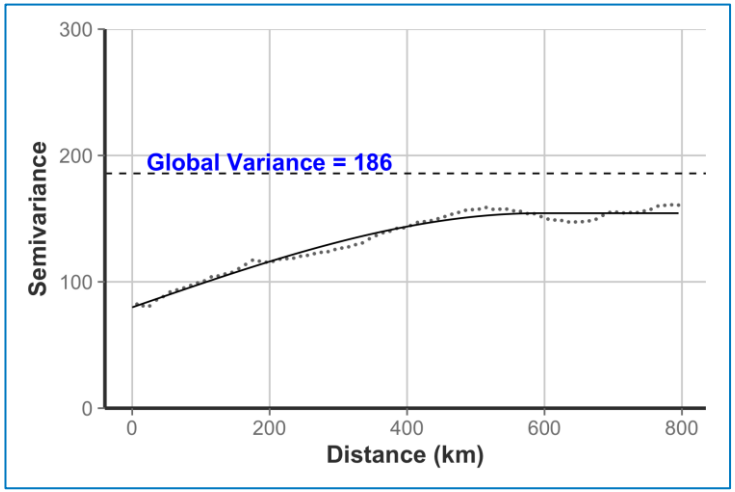
Estimating Shallow, Low-Temperature Geothermal Resources

Observations of latitude, longitude, temperature, and depth.



Experimental variogram (points) and fitted variogram model (line) for residuals from regression model.



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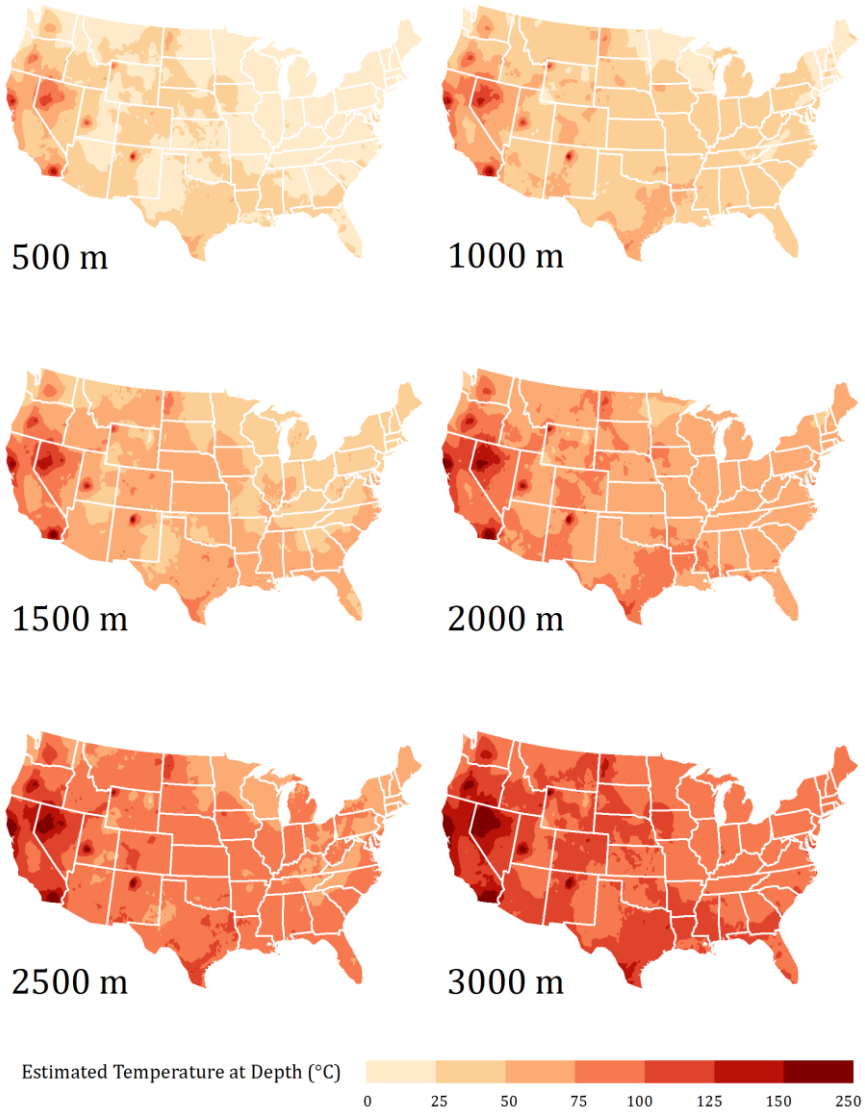
Estimating Shallow, Low-Temperature Geothermal Resources

Temperature at depth maps resulting from kriging.



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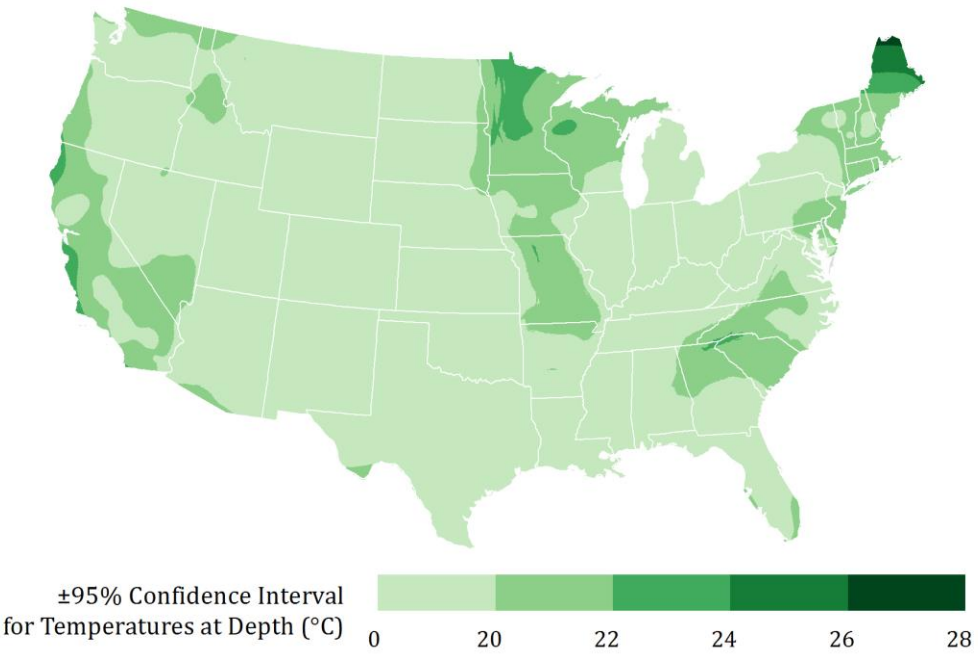

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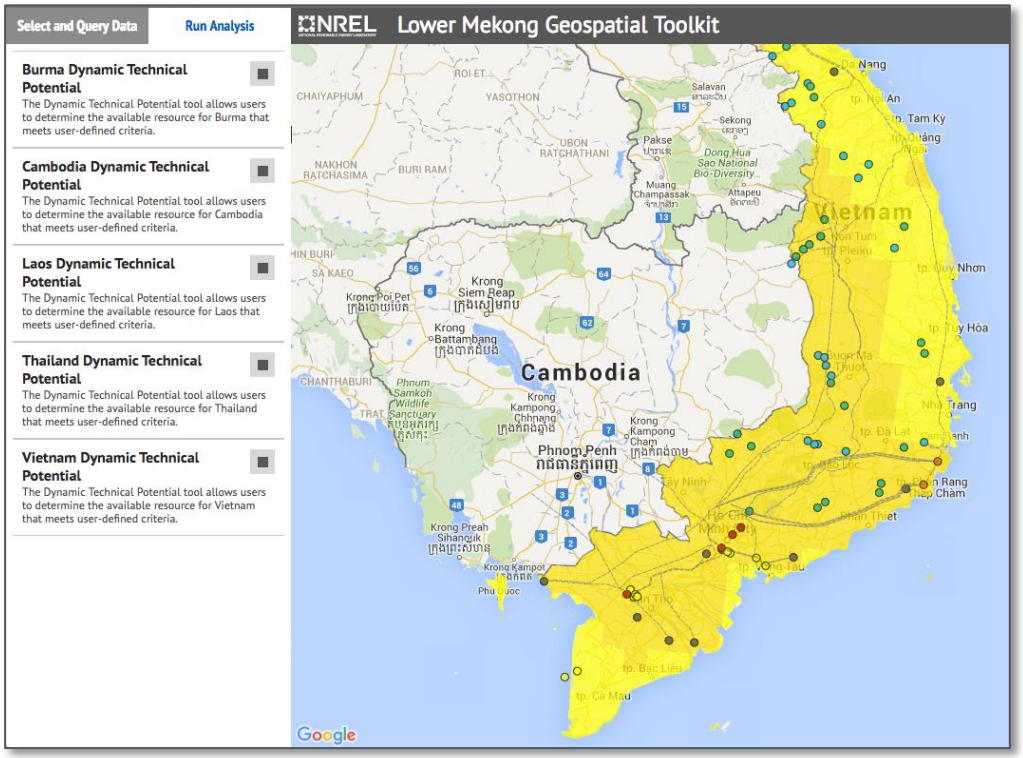

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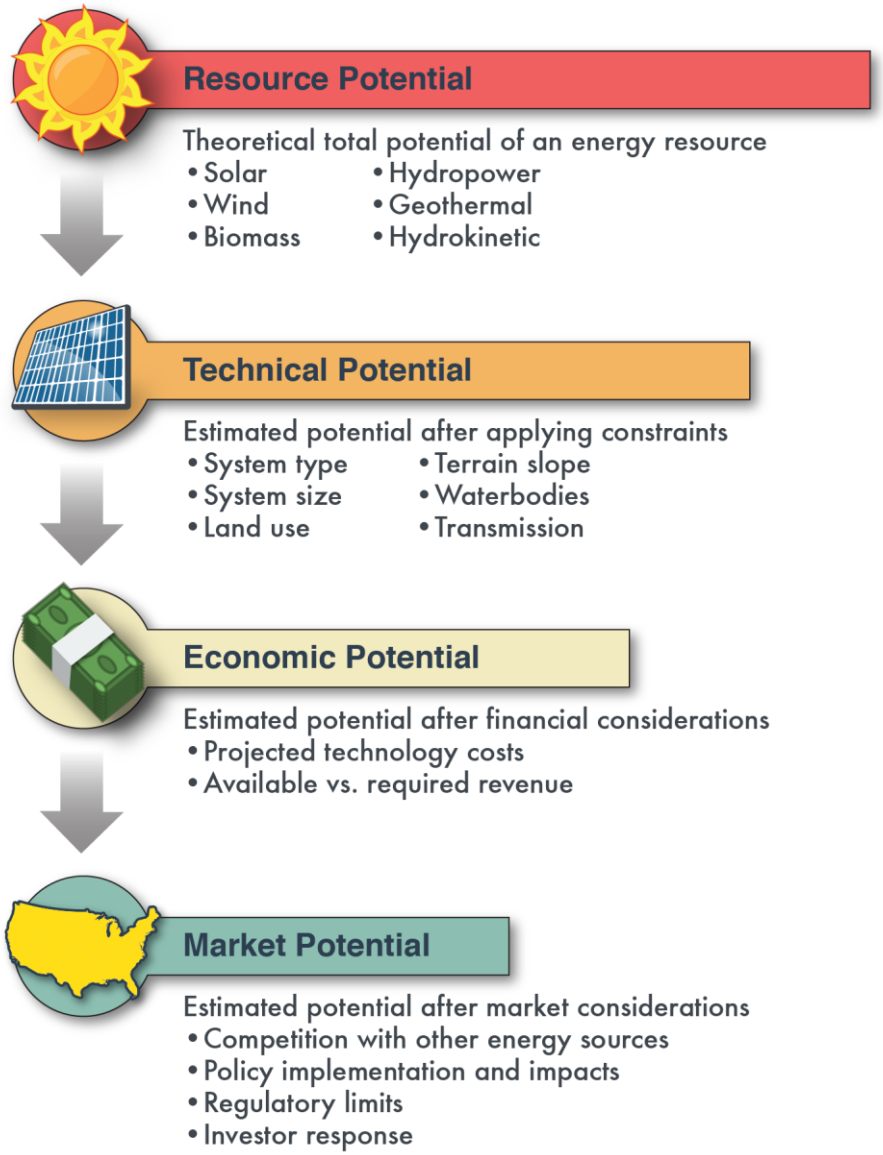
Geospatial Analysis *for* **Renewable Energy**

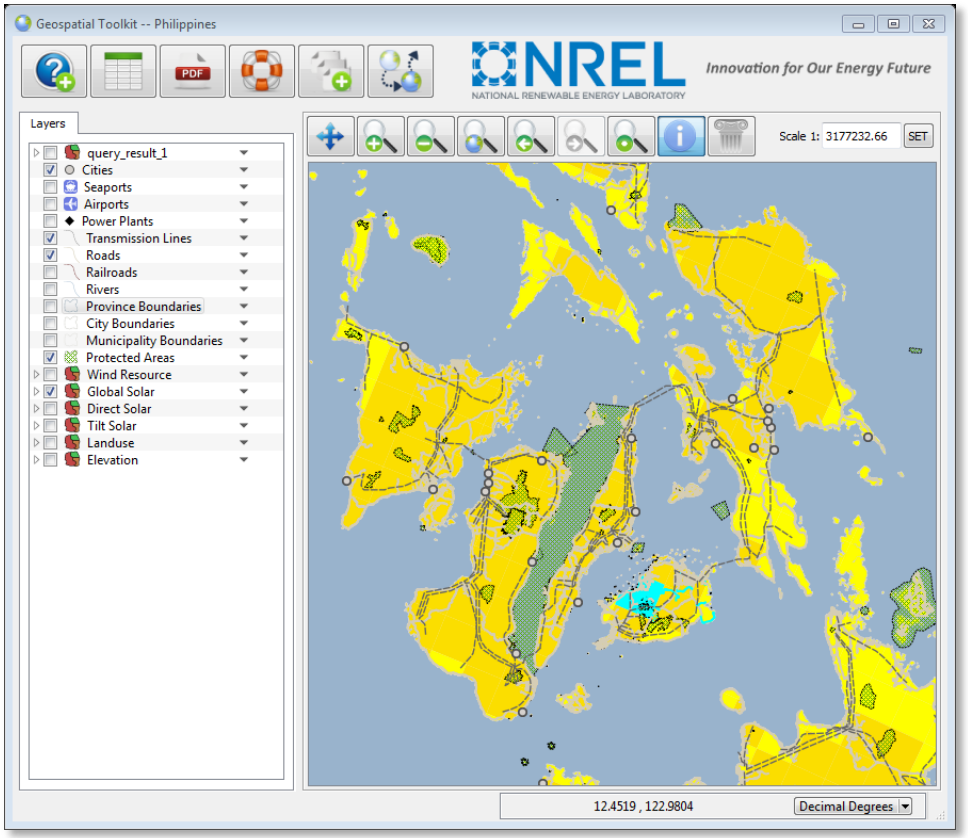
- Where do we start?



Enterprise Geospatial Toolkit (EGsT)

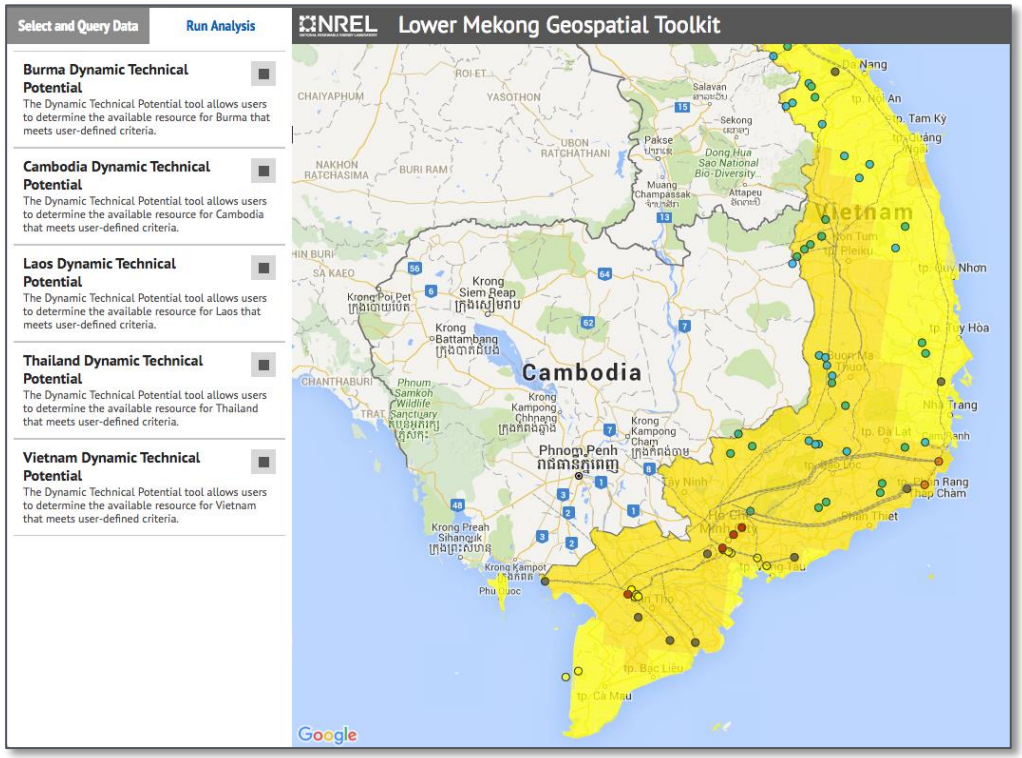
First, What is the Desktop Geospatial Toolkit?

- 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



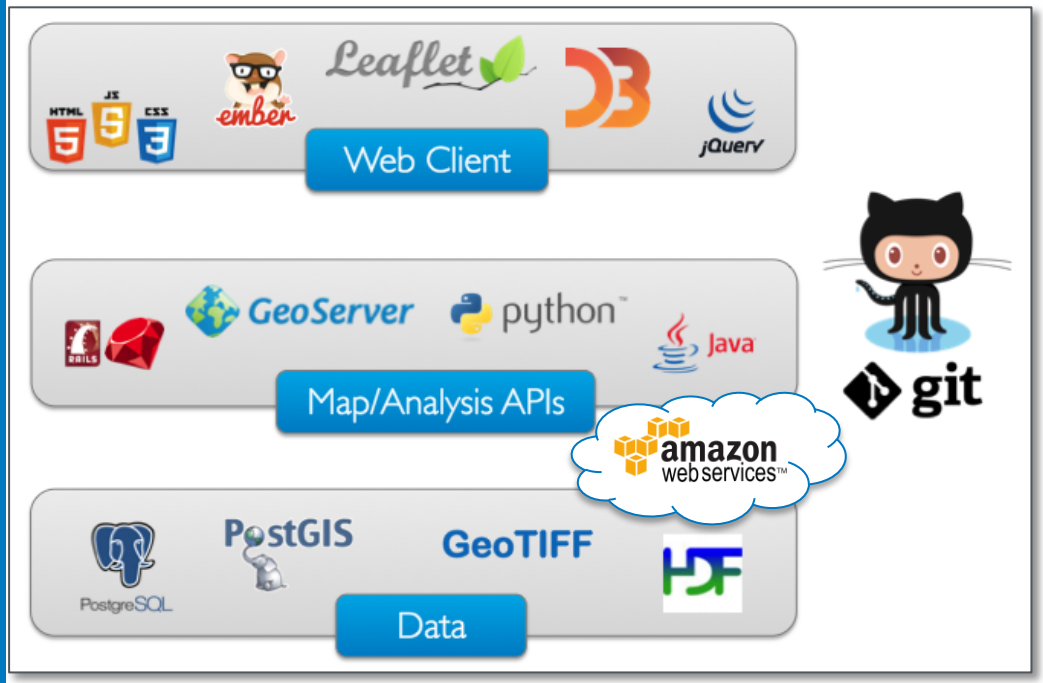
Now… What is the Enterprise Geospatial Toolkit (EGsT)?

- 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



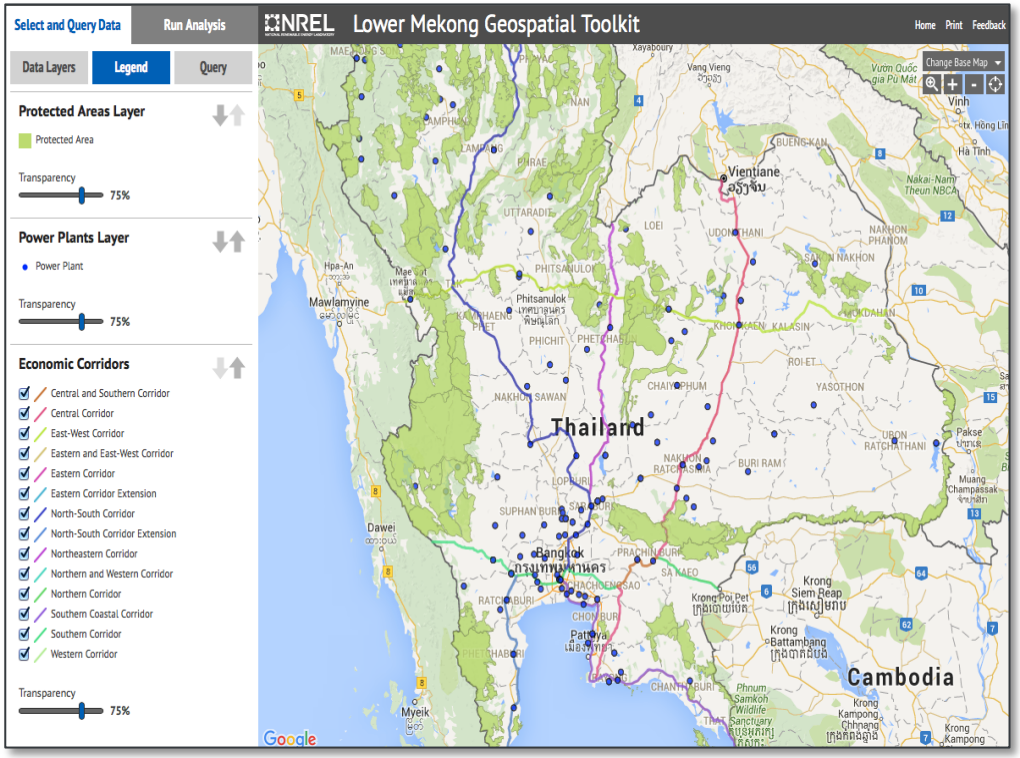
EGsT Architecture

- 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



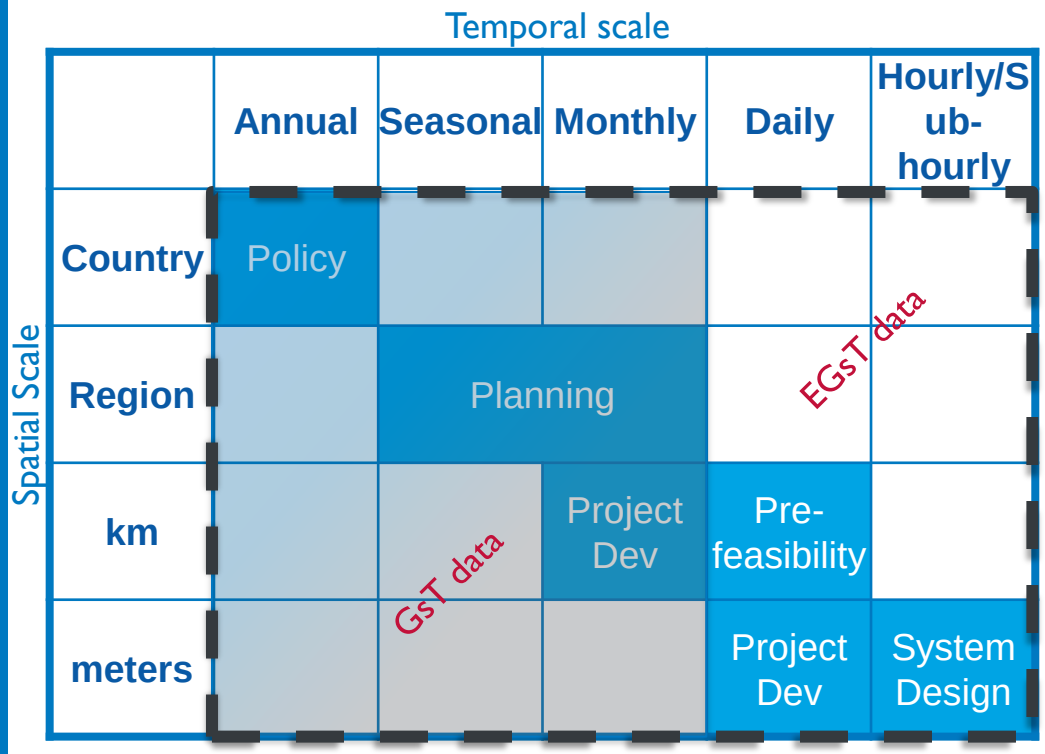
EGsT Data

- 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
  - 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, pre-feasibility assessment, or system design
- One stop for relevant geospatial and spatiotemporal data for renewable energy

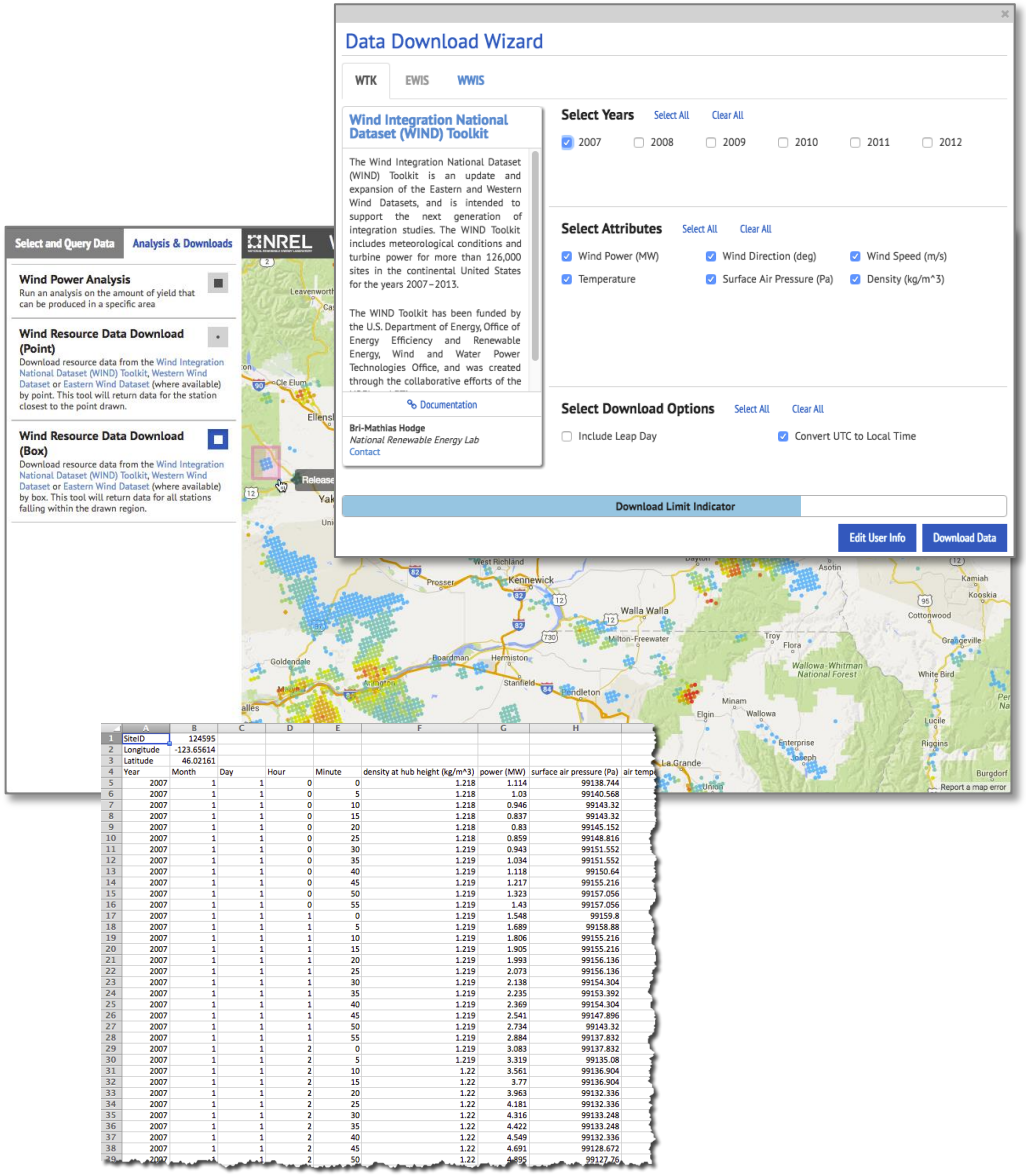


** Data and Analysis Various by Country/Region*

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



SiteID	124595						
Longitude	-123.65614						
Latitude	46.02161						
Year	Month	Day	Hour	Minute	density at hub height (kg/m^3)	power (MW)	surface air pressure (Pa)
2007	1	1	0	0	1.218	1.114	99138.744
2007	1	1	0	5	1.218	1.03	99140.568
2007	1	1	0	10	1.218	0.946	99143.32
2007	1	1	0	15	1.218	0.837	99143.32
2007	1	1	0	20	1.218	0.83	99145.152
2007	1	1	0	25	1.218	0.859	99148.816
2007	1	1	0	30	1.219	0.943	99151.552
2007	1	1	0	35	1.219	1.034	99151.552
2007	1	1	0	40	1.219	1.118	99150.64
2007	1	1	0	45	1.219	1.217	99155.216
2007	1	1	0	50	1.219	1.323	99157.056
2007	1	1	0	55	1.219	1.43	99157.056
2007	1	1	1	0	1.219	1.548	99159.8
2007	1	1	1	5	1.219	1.689	99158.88
2007	1	1	1	10	1.219	1.806	99155.216
2007	1	1	1	15	1.219	1.905	99155.216
2007	1	1	1	20	1.219	1.993	99156.136
2007	1	1	1	25	1.219	2.073	99156.136
2007	1	1	1	30	1.219	2.138	99154.304
2007	1	1	1	35	1.219	2.235	99153.392
2007	1	1	1	40	1.219	2.369	99154.304
2007	1	1	1	45	1.219	2.541	99147.896
2007	1	1	1	50	1.219	2.734	99143.32
2007	1	1	1	55	1.219	2.884	99137.832
2007	1	1	2	0	1.219	3.083	99137.832
2007	1	1	2	5	1.219	3.319	99135.08
2007	1	1	2	10	1.22	3.561	99136.904
2007	1	1	2	15	1.22	3.77	99136.904
2007	1	1	2	20	1.22	3.963	99132.336
2007	1	1	2	25	1.22	4.181	99132.336
2007	1	1	2	30	1.22	4.316	99133.248
2007	1	1	2	35	1.22	4.422	99133.248
2007	1	1	2	40	1.22	4.549	99132.336
2007	1	1	2	45	1.22	4.691	99128.672
2007	1	1	2	50	1.22	4.895	99127.76

** in development*

Big Data Downloads

Users

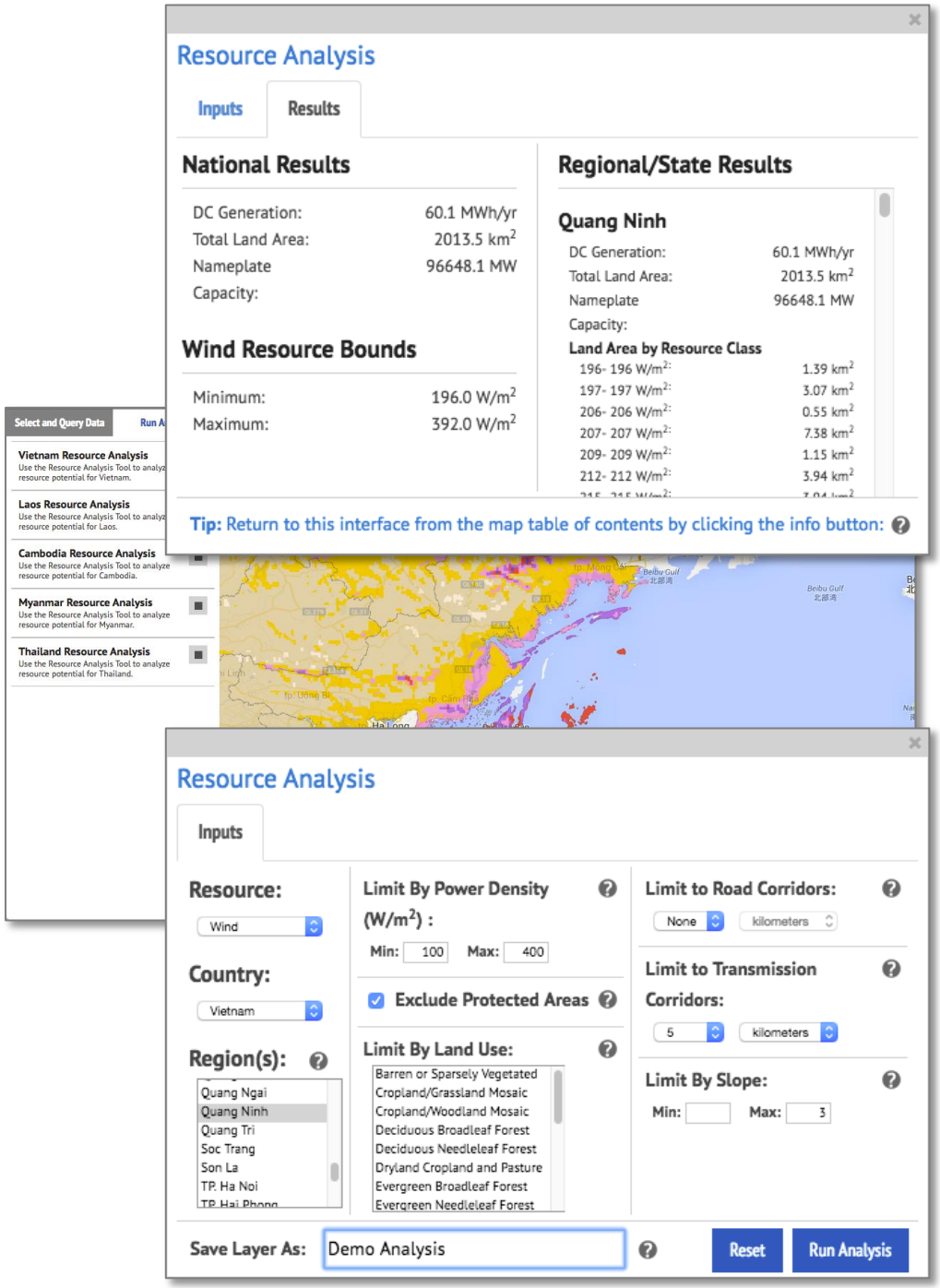
- Electric utility consultants
- Utility planners
- Academics
- Project Developers
- Energy Analysts
- Technology Engineers

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



Technical Potential

Users

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

Use Cases

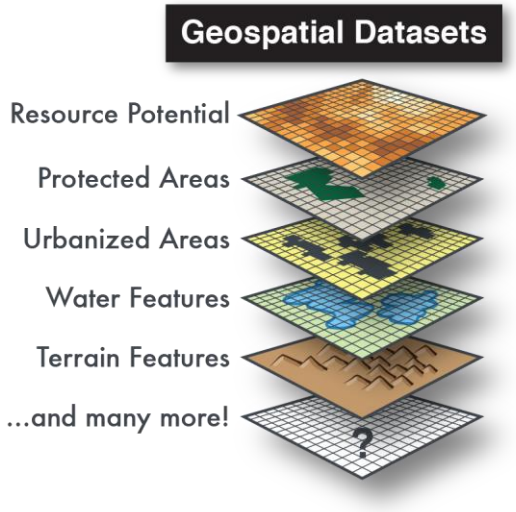
- Policy analysis – evaluation of barriers and impacts to RE targets
- Base data for grid integration analysis
  - Production cost models
  - Capacity expansion models
- Land use and environmental impact analysis
- Utility-scale site identification

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



Renewable Energy Zone Support Tool

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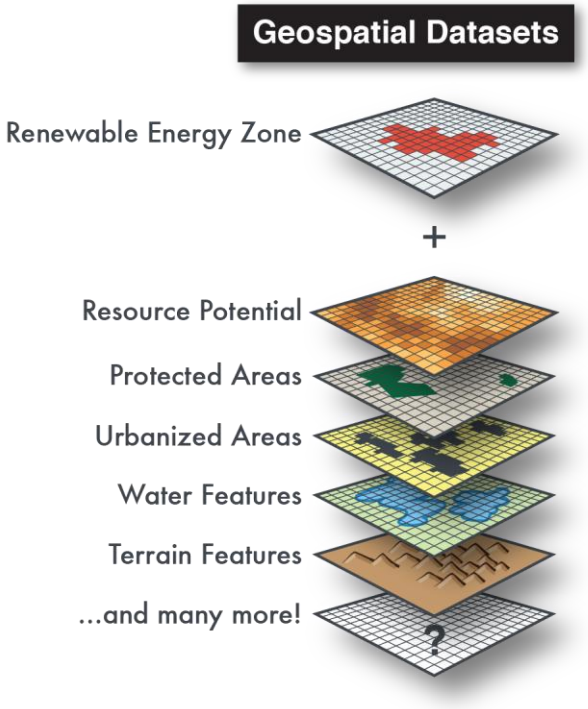
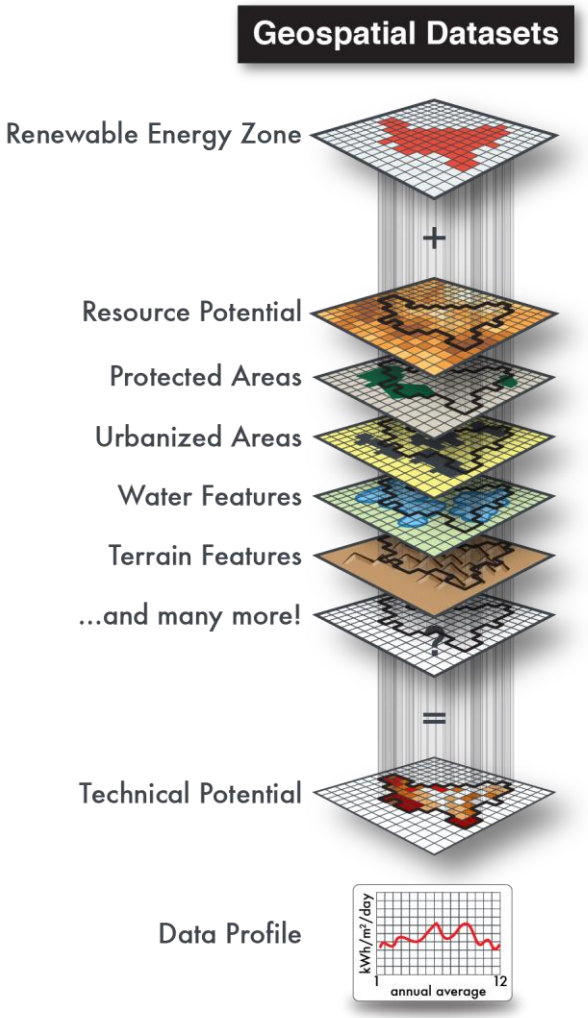


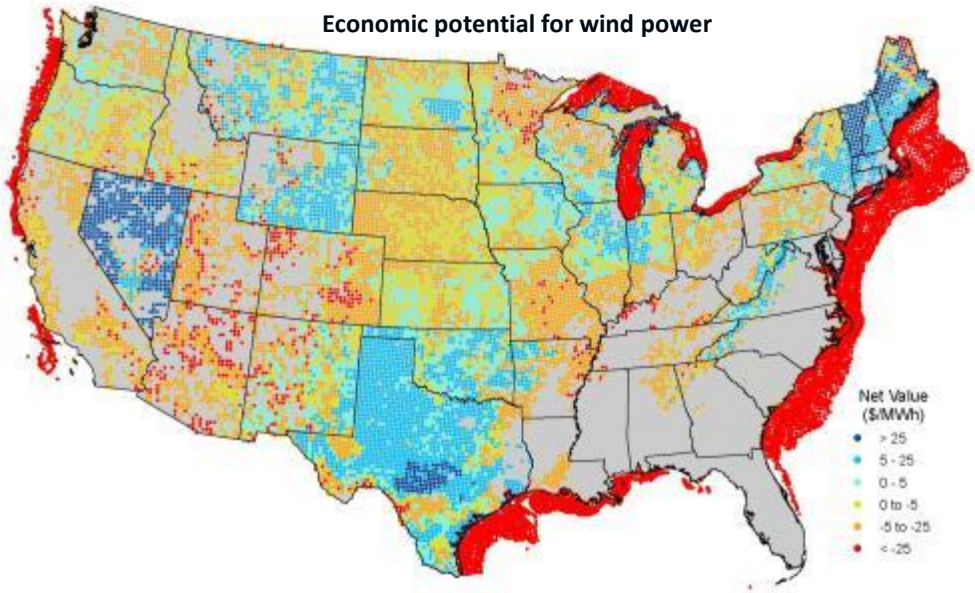
Renewable Energy Zone Support Tool

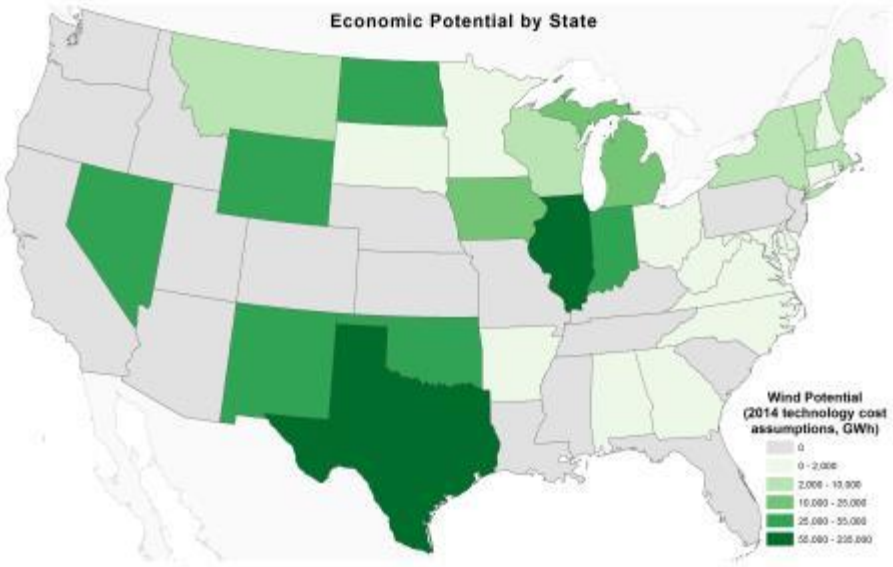
- Allow users to visualize, download, and interact with the zones identified by stakeholders in the REZ analysis framework



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 sub-state level

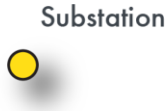




Note: Graphics for illustrative purposes only

Grid Integration Support Tool

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



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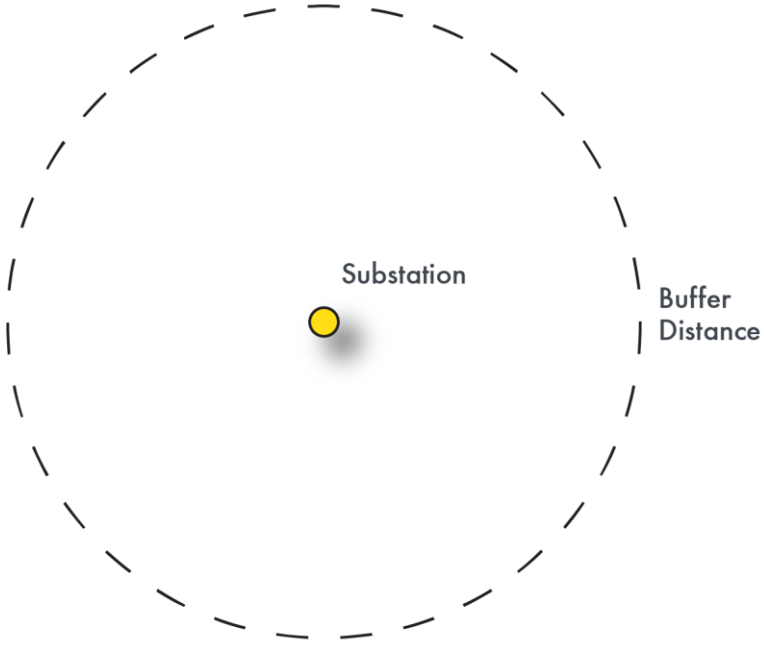

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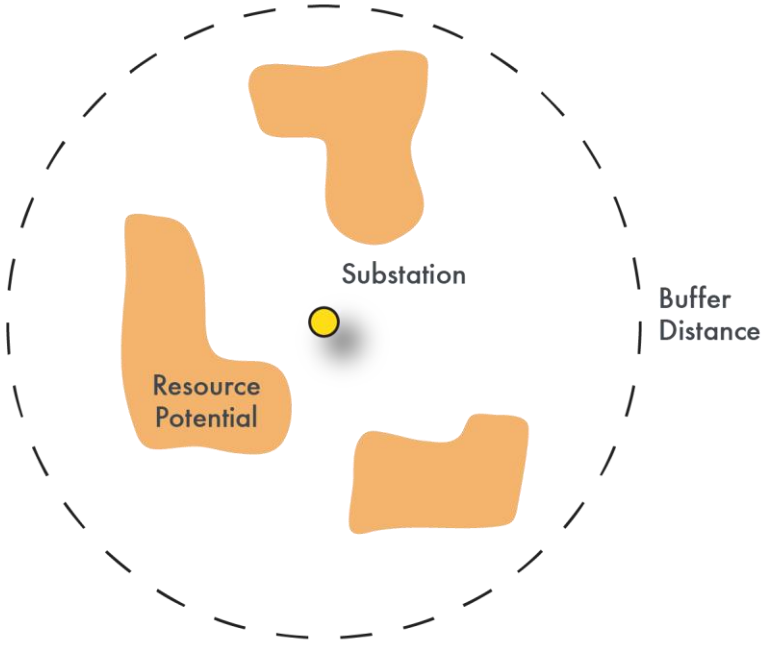

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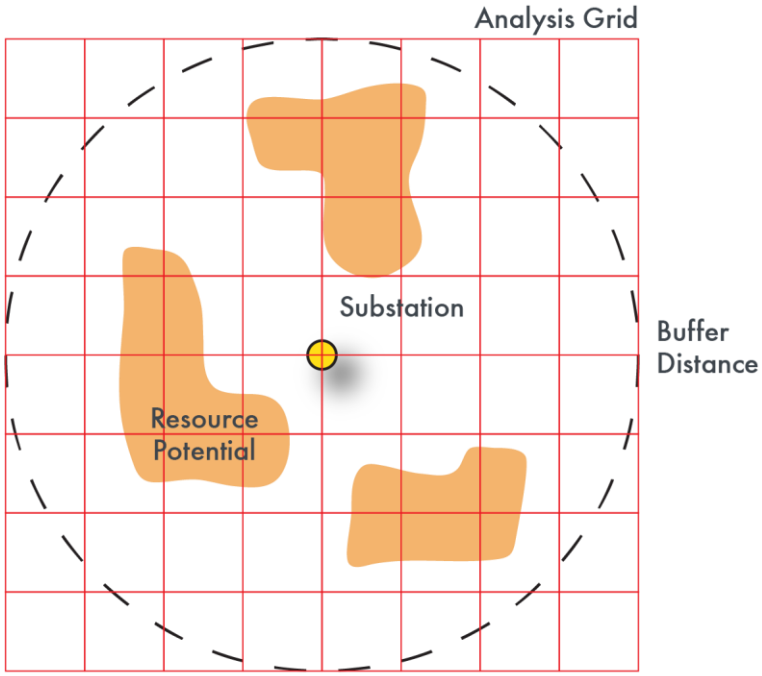

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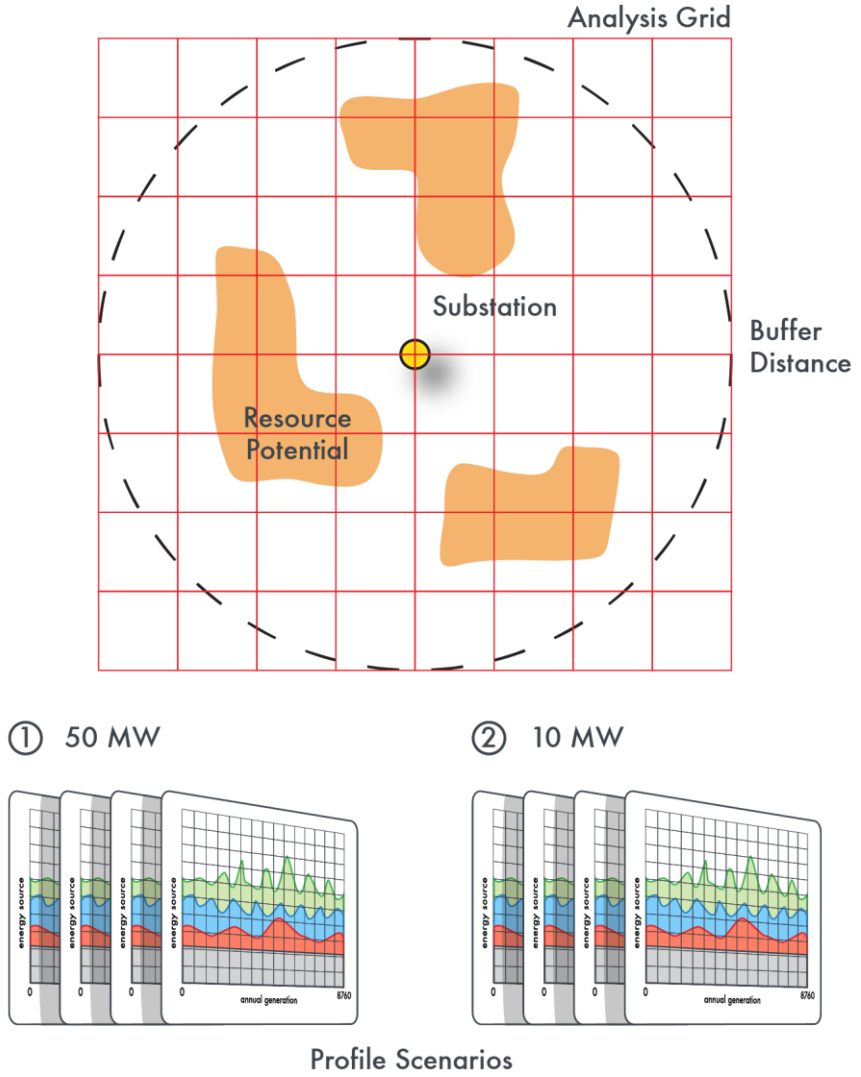

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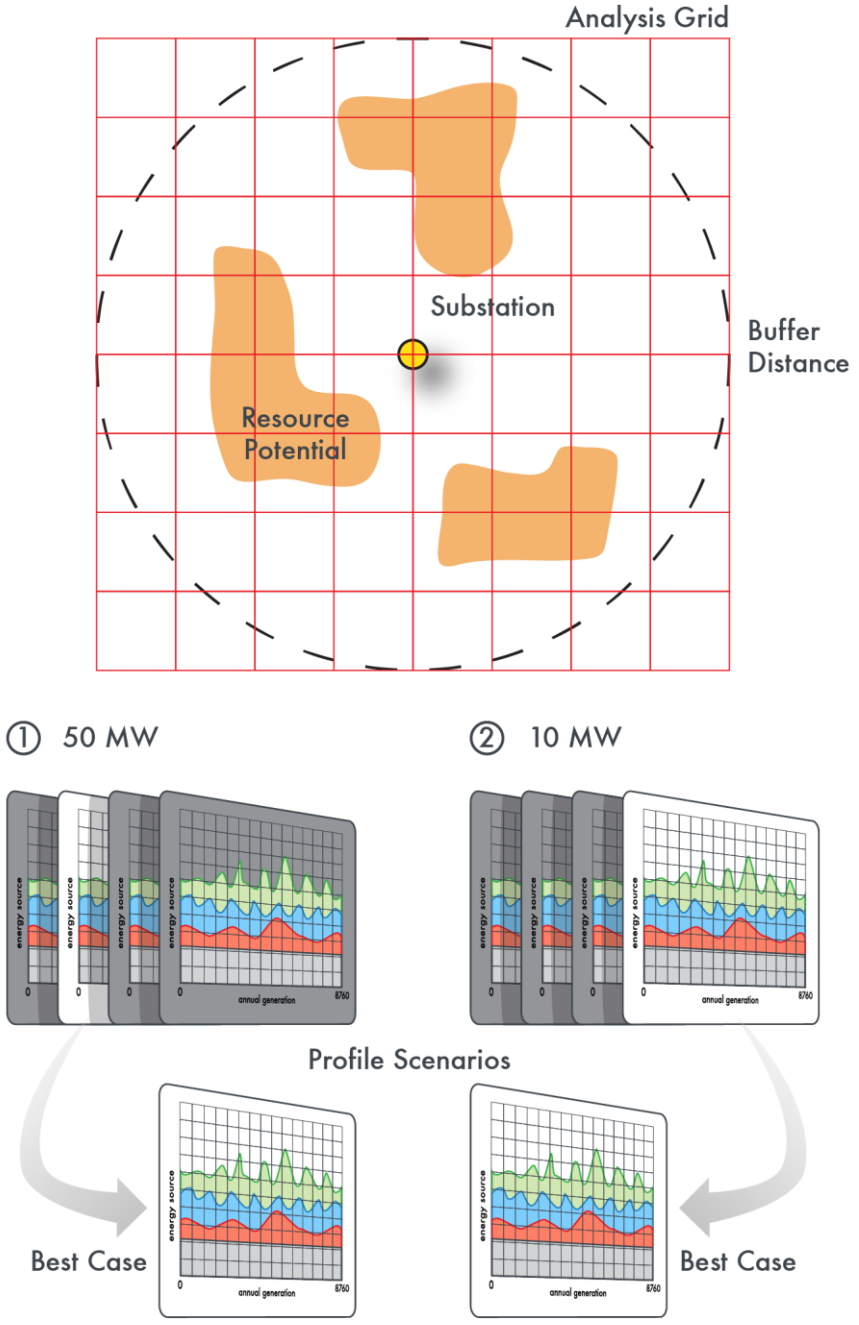
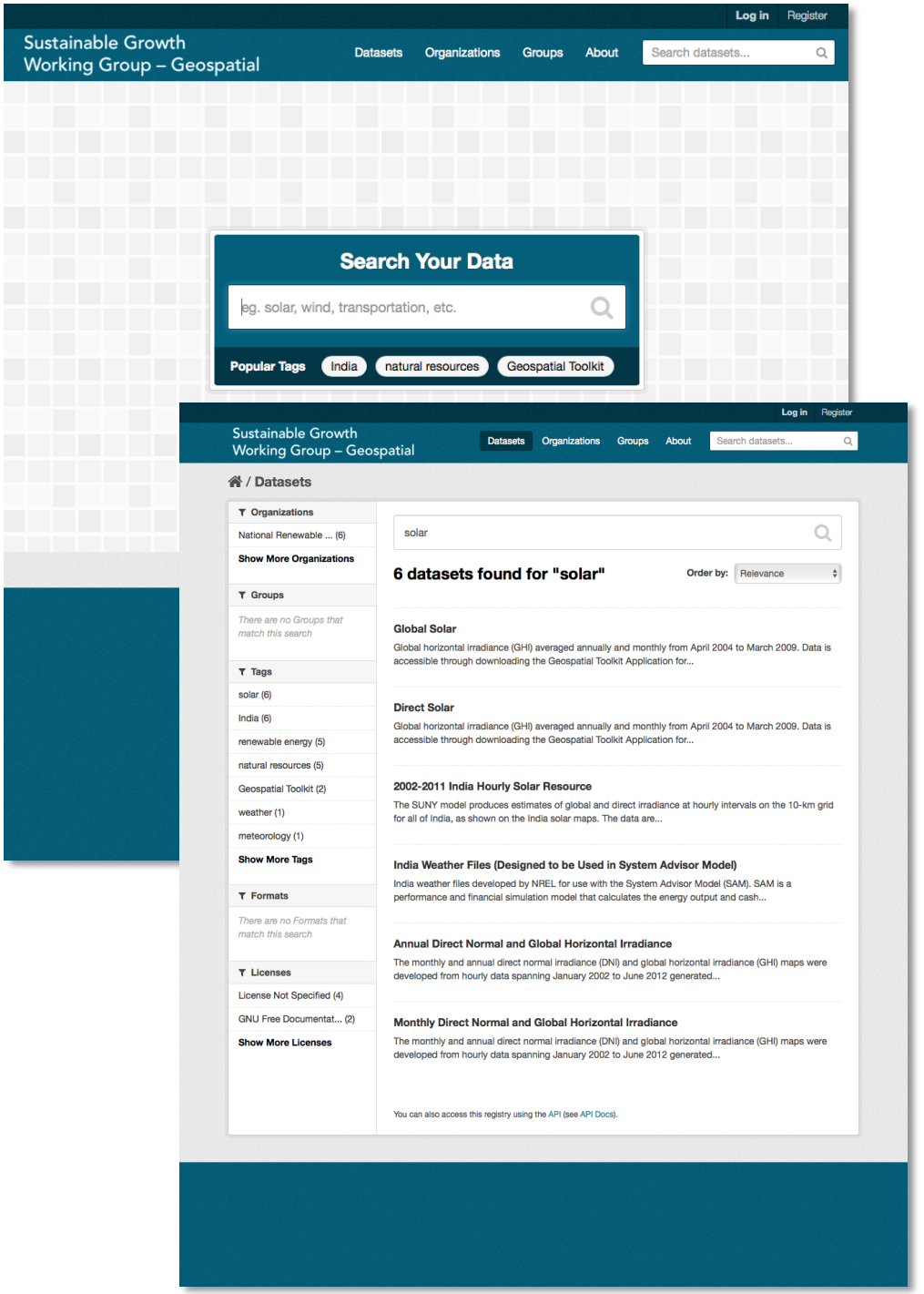


Metadata Repository Integration

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



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/gst-philippines

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

Group Discussion

Thank You

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Resources:

- Geospatial Toolkit downloads: http://www.nrel.gov/international/geospatial_toolkits.html
- Enhancing Capacity for Low Emission Development Strategies: www.ec-leds.org

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