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Renewable Energy Planning, Analysis, and the Data that Make Them Possible: An Assessment for Cambodia

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Purpose of Assessment

- To facilitate the **informed use of existing data** by highlighting applications for these data as they relate to priority RE analyses
- To **inform future investments in data collection** and development by identifying significant data gaps and providing guidance on how to fill these gaps

Space and Time: The Key Dimensions of Data

Temporal scale

Annual Seasonal Monthly Daily Hourly

Spatial Scale

Country

Region

Kilometer

Meter

Target-setting

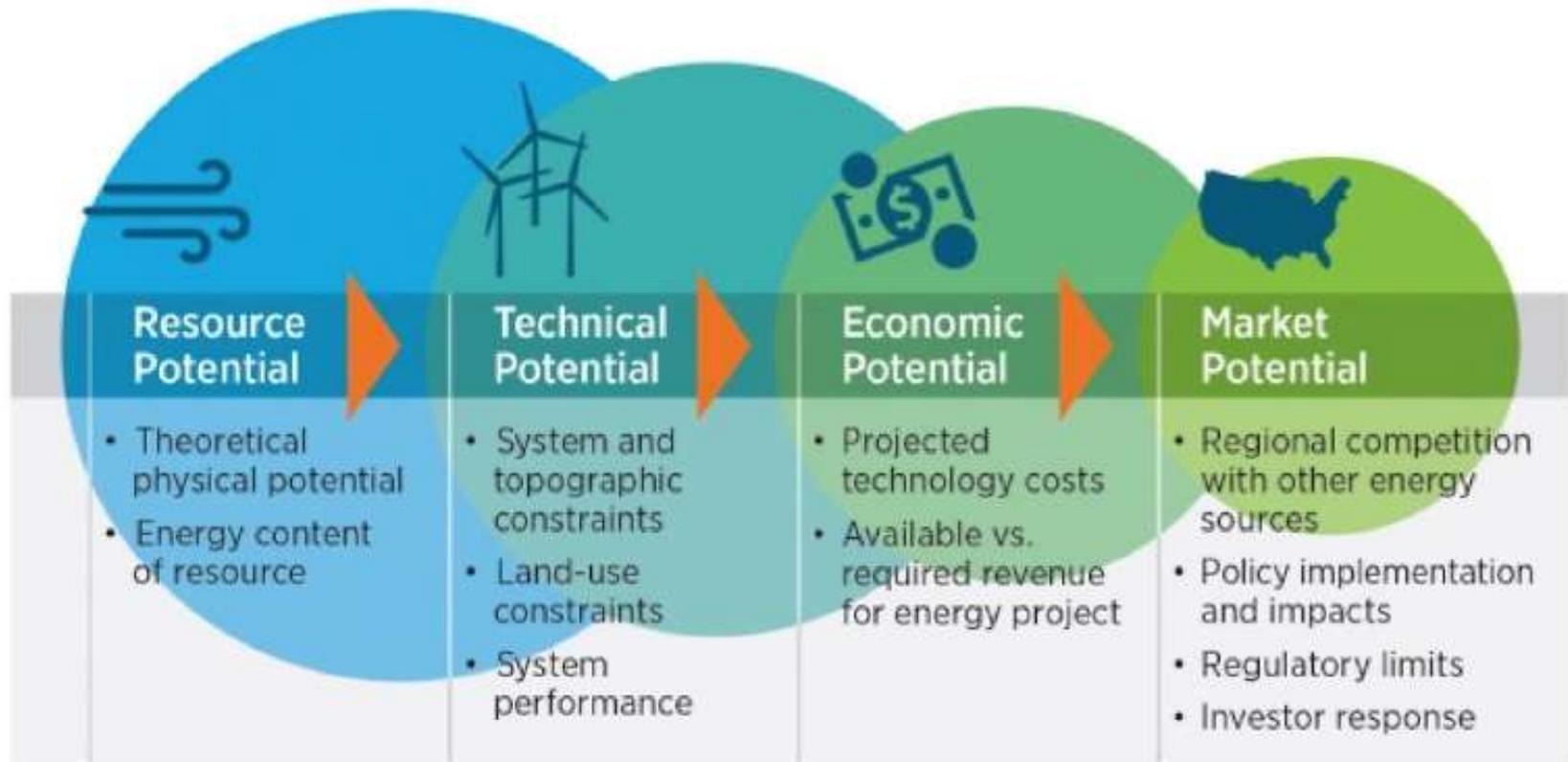
Capacity expansion

Grid Integration

Priority Analysis Topics

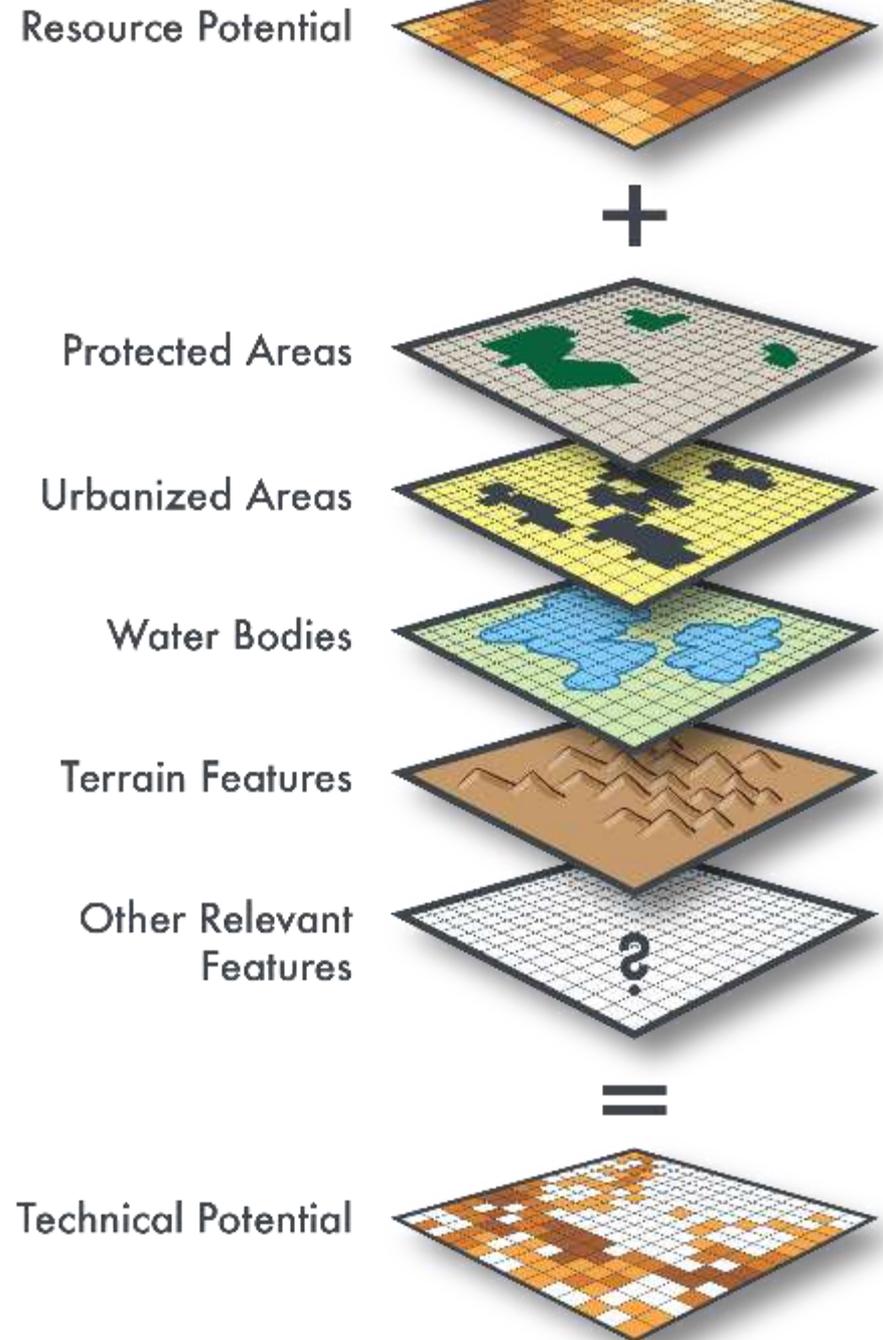
- Technical potential
- Economic potential
- RE Zones
- Grid integration studies
- Distributed solar PV
- Resilience/risk
- Energy access

What is “Energy Potential”?



Technical Potential

- The achievable energy capacity and generation of a particular technology given system performance, topographic limitations, environmental, and land-use constraints
 - *Does not consider technology costs*

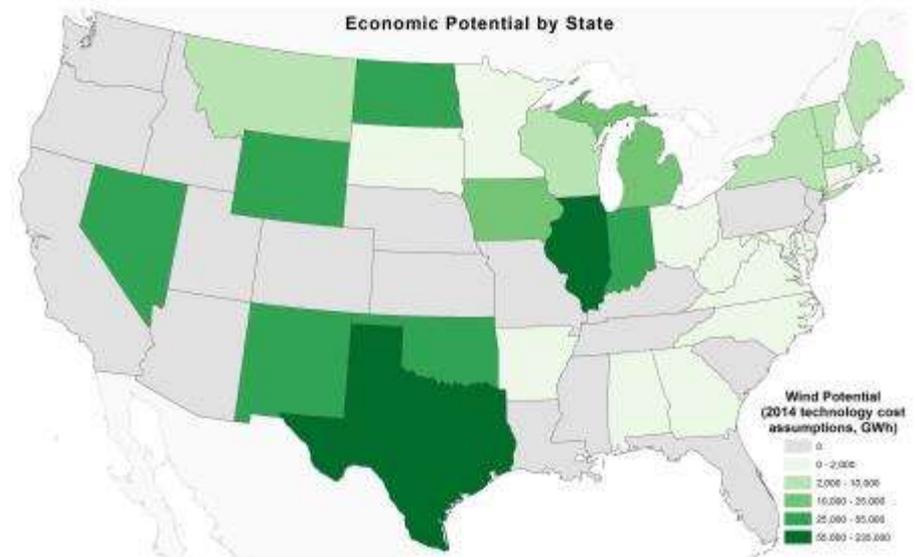
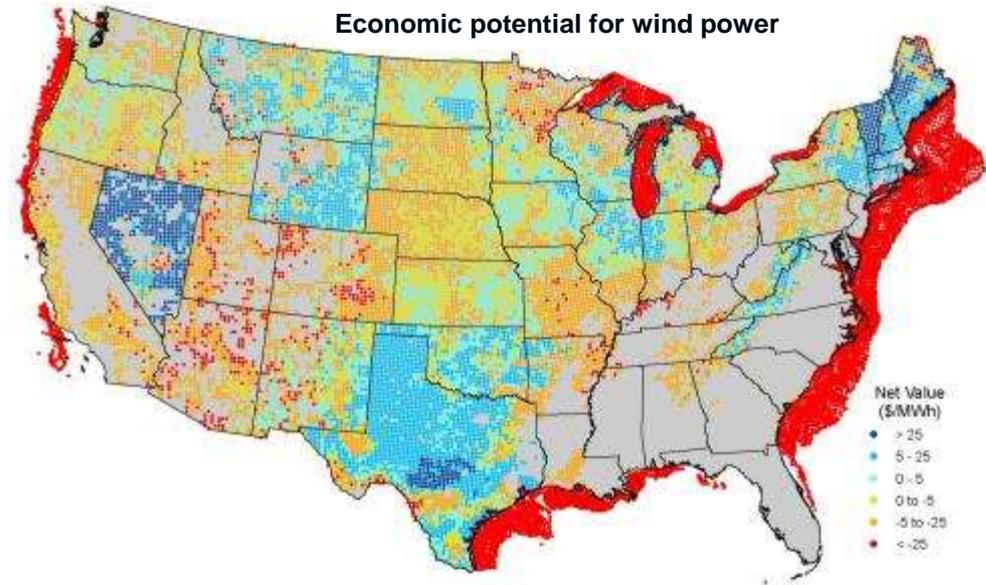


Technical Potential – Data Requirements

- **Resource** (*annual average temporal resolution sufficient**)
 - Annual average solar (~10km), wind (<2km*), biomass (province, district, on-site), geothermal, hydro, etc.
- **Environmental**
 - Land-use, land-cover, protected areas, sensitive flora and fauna, rivers, lakes, topography, elevation
- **Other**
 - Population, land ownership, technology assumptions

Economic Potential

- Economic potential is defined as the subset of the available resource technical potential where the cost required to generate the electricity is below the revenue available in terms of displaced energy and displaced capacity

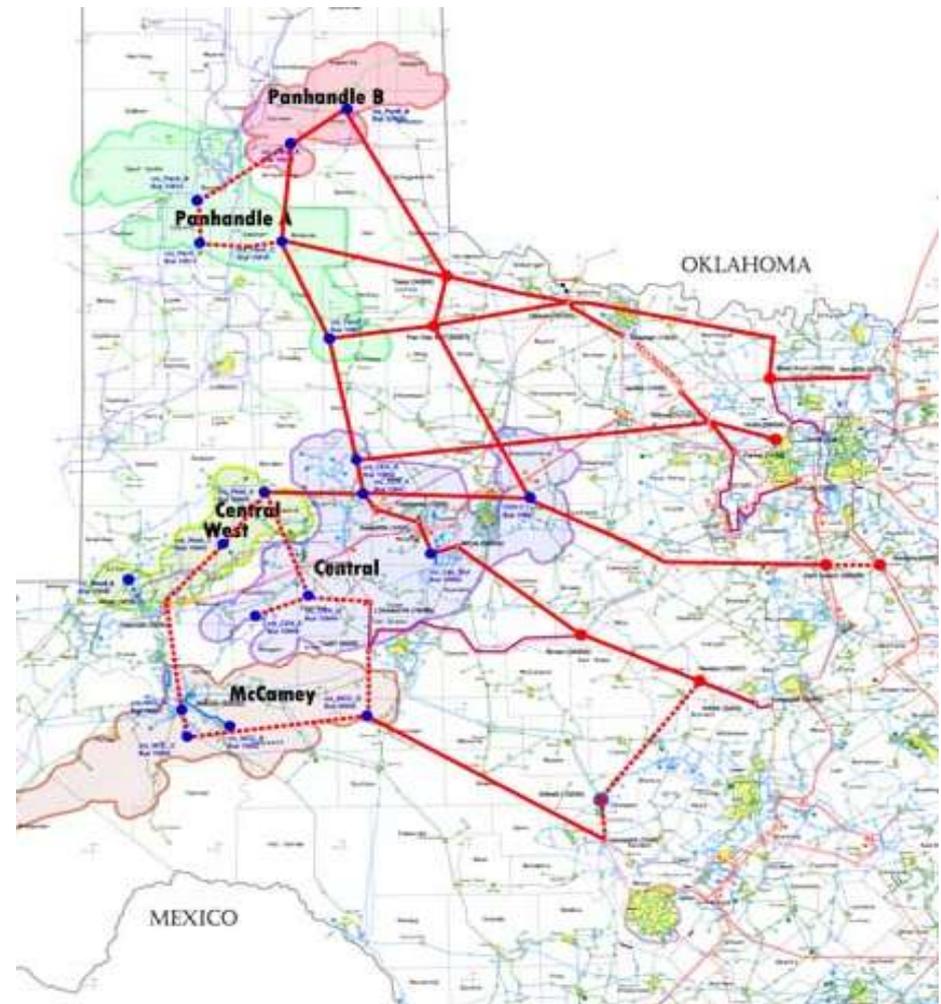


Economic Potential – Data Requirements

- **Same requirements as technical potential, plus:**
 - **Hourly solar and wind resource***
 - **Seasonal data for biomass resources***
 - **Levelized Cost of Energy (LCOE) for each technology**
 - Plant construction cost
 - Operations and maintenance cost
 - Fixed operating cost
 - Variable operating cost
 - Fixed charge rate
 - Intra-regional transmission cost
 - **Levelized Avoided Cost of Energy (LACE)**
 - Marginal generation or wholesale energy market price
 - Projected energy price

Renewable Energy Zones

- What are RE Zones?
 - Areas with a high concentration of high-quality, easily-developable renewable energy potential
 - A tool for transmission planning



Renewable Energy Zones – Data Requirements

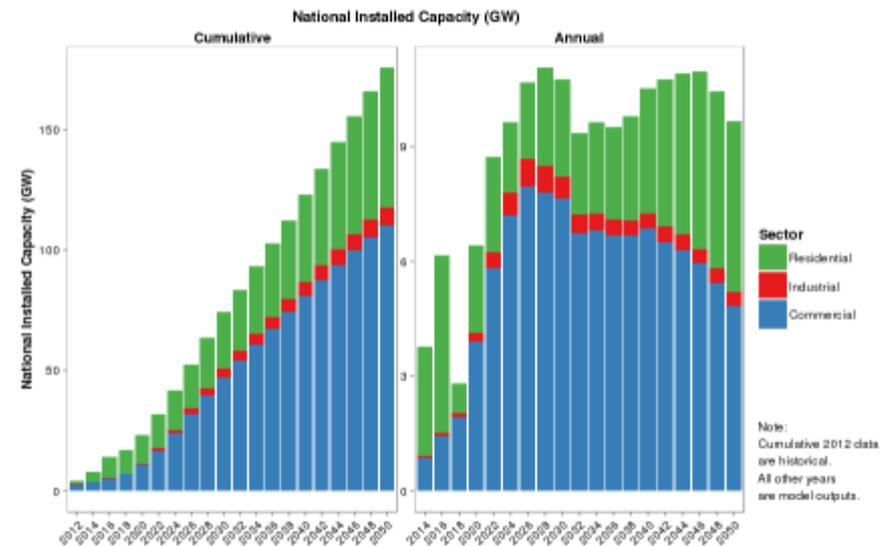
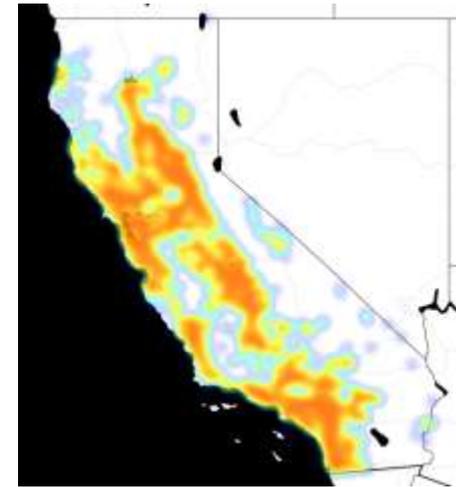
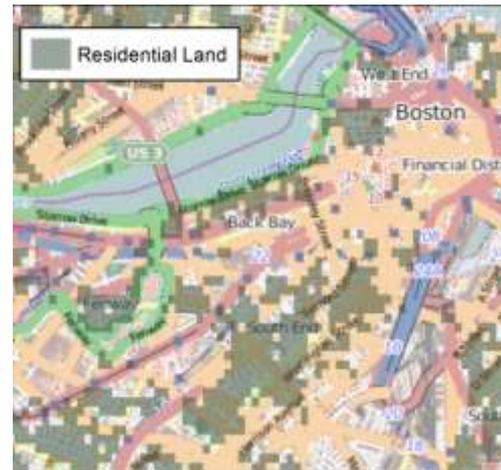
- **Same requirements as technical potential, plus:**
 - **Infrastructure**
 - Electric transmission lines [detailed, non-hypothetical]
 - Electric substations [detailed, non-hypothetical]
 - Roads
 - Rail
 - Navigable rivers
 - Ports
- **Economic potential requirements are helpful**
(*not necessarily required**)

Grid Integration – Data Requirements

- **Same requirements as technical potential, plus*:**
 - Hourly (or sub-hourly) solar and wind resource
 - Seasonal data for biomass resources
 - Hourly (or sub-hourly) load
 - If the focus is on capacity expansion, need load and RE resource profiles for a typical year*
 - If the focus is on operations, need load data and RE resource data that are *time-synchronous* (same year and time-steps)
 - Existing and planned electric infrastructure
 - Transmission lines and nodes
 - Generator locations and operating characteristics (e.g., capacity, minimum stable level, ramp rate, heat rates, outage rates, fuel costs...)

Distributed solar photovoltaic (DGPV)

- Connected to the distribution network of a utility system
- Connected “behind-the-meter”
- Smaller scale in nature
- In most cases, not owned or operated by distribution utility



(Top Left): Evaluate adoption potential for each 200m² cell; (Top Right): Spatial focus permits regional predictions; (Bottom): Results from BAU-Mid Costs Scenario in ITC Extension analysis

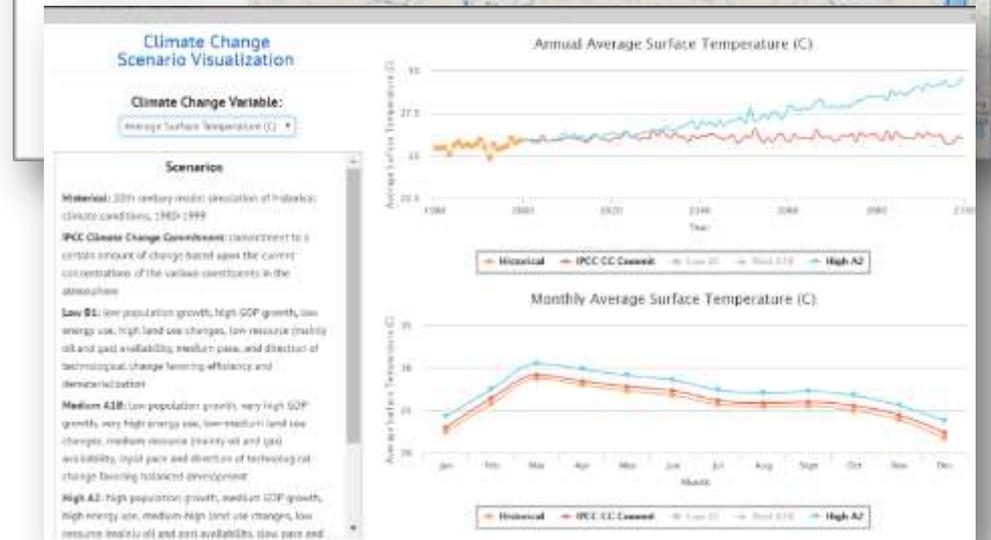
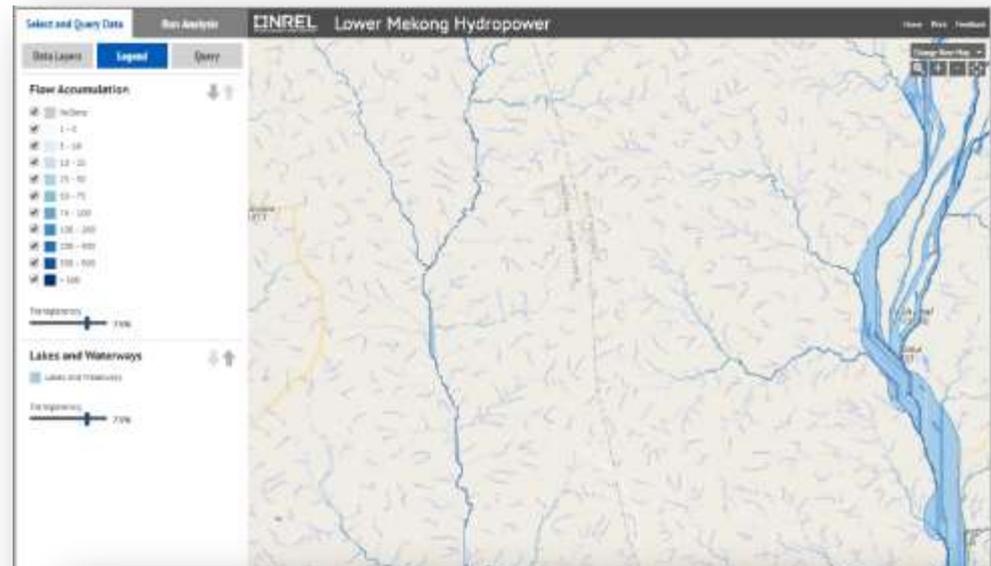
DGPV – Data Requirements

- **If we want to gain a basic understanding of the technical potential...**
 - Hourly solar resource
 - Building Inventory microdata
 - Representation of current and future building stock (counts, building type/area, occupancy rates, roof area, roof suitability)
- **If we want to model DGPV diffusion... (in addition to above)**
 - Hourly current and future Load
 - Representation of end-uses
 - Sectors, applications for DG
 - Current and future retail rate prices
 - Current and future incentives, net metering
 - Financing assumptions
 - Technology cost and performance assumptions
 - Current adoption levels
 - Where, how much

Risk and Resiliency

No standard definition, but example questions include:

- How does energy resource availability vary (e.g., by season or hour)?
- How vulnerable are future generation and infrastructure investments to natural disasters?
- Where can RE deployment potentially contribute to energy reliability (e.g., by providing backup to critical loads)?
- How might energy development impact food and water security?

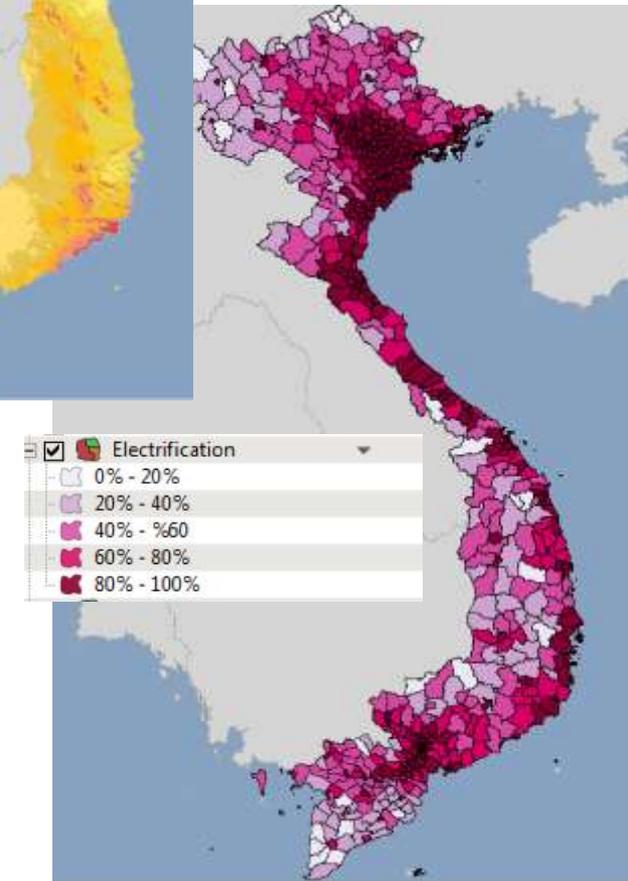
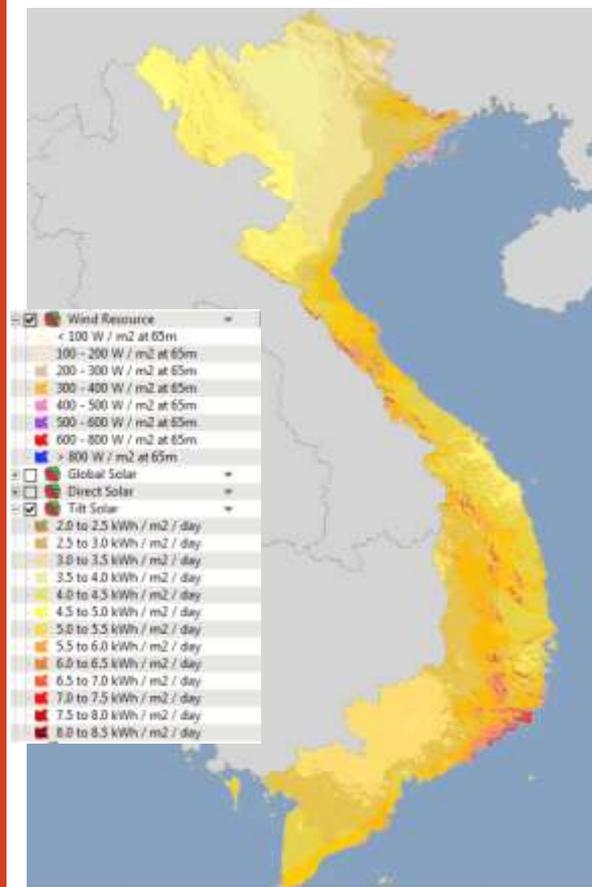


Risk and Resiliency

- **Energy resource availability**
 - E.g., annual, monthly (and hourly*) availability of hydro, biomass, wind, solar, etc.
- **Natural Hazards and Severe Weather**
 - Tsunami frequency, landslide frequency, fire risk, earthquake frequency, drought events, flood risk, heatwave risk, tornadoes risk, etc.
- **Infrastructure**
 - Electric transmission lines, substations, natural gas pipelines, roads, rail, navigable rivers, ports, power plants, critical loads, etc.
- **Food and water security**
 - Productivity of croplands, distribution of population relying on subsistence farming, access to electricity, water and other critical infrastructure, poverty, energy technology footprint, ...

Energy Access

- Where might renewables support the electrification of off-grid communities?



Electrification data requirements

- **Same requirements as technical potential, plus:**
 - Population distribution
 - Poverty rates [district-level or higher resolution]
 - Electrification rates [district-level or higher resolution]
 - Existing and planned transmission lines and substations (*not required if high-resolution electrification rates are available**)

Cambodia Data Assessment Highlights

Organization

- Data collection is organized into the following categories
 - Renewable energy resource (wind, solar, biomass, geothermal, and hydropower)
 - Power network
 - Ancillary meteorology
 - Environmental
 - Market and demand
 - Transportation
 - Administrative other

**This preliminary data assessment is based on our team's efforts to mine primarily publicly-accessible data sources, with some input from Cambodian stakeholders on other data sources. This list is not exhaustive, and we welcome guidance on additional data sources!*

Resource – Wind

- **Highlights:** Highest quality, freely available wind resource available from the Danish Technical University (DTU)
 - Long-term annual average wind speed at 50m, 80m, 200m
 - Long-term annual average wind power density at 50m, 80m, 200m
- **Analysis Applications (existing data):** Technical Potential, Economic Potential, RE Zones, Resilience and Risk, Electrification
- **Potential gaps:** Hourly wind speed data, which would enable research of existing/future turbine performance/cost, wind power plants, and enable grid integration studies

Resource – Solar

- **Highlights:** Highest quality, freely available solar resource data available from the World Bank (WB)
 - Long-term annual average global horizontal irradiance
 - Long-term annual average direct normal irradiance
 - Long-term annual average optimal-tilt PV electricity
- **Analysis Applications (existing data):** Technical Potential, Economic Potential, RE Zones, Resilience and Risk, Electrification
- **Potential gaps:** Hourly solar irradiance data, to enable research of existing/future utility-scale PV, rooftop PV, and enable grid integration analysis

Resource – Biomass

- **Highlights:** Freely available, partial biomass resource data from Ministry of Agriculture, Forestry, and Fisheries by province
 - Annual crop residues (rice husk, rice straw, cassava stock, and maize cob)
 - National estimates of livestock production also available from Asian Development Bank (ADB) for assessing biogas potential
- **Analysis Applications (existing data):** Technical Potential, Economic Potential, RE Zones, Resilience and Risk, Electrification
- **Potential gaps:** Creation or procurement of more detailed crop residues data (e.g. district, sq.km, on-site), biogas estimates at finer than national level resolution, forest residues data (e.g. logging residues, mill residues).

Resource – Geothermal

- **Highlights:** Public searches did not turn up information on geothermal resource potential for Cambodia
- **Analysis Applications (existing data):** N/A
- **Recommendations:** Create a database/list and maps of name and locations of known hot springs and other geothermal anomalies.

Resource – Hydropower

- **Highlights:** Operational, potential, under construction, and under study hydropower dam locations with MW potential
- **Analysis Applications (existing data):** Technical Potential, Economic Potential, Resilience and Risk, Electrification
- **Possible gaps:** Seasonal output for grid integration studies

Power Network

- **Highlights:** Publicly accessible transmission line and substation data derived from government agency and Electricité du Cambodge information
- **Analysis Applications (existing data):** Economic Potential, RE Zones, Grid Integration, Resilience and Risk, Electrification
- **Possible gaps:** GIS dataset of medium and lower voltage electricity networks

Ancillary Meteorology

- **Highlights:** Data is available from NASA Surface meteorology and Solar Energy website, however is spatial coarse and contains daily averages.
- **Analysis Applications (existing data):**
Resiliency and Risk
- **Potential gaps:** Hourly ancillary meteorology data

Environment

- **Highlights:** Good coverage from diverse regional and global entities
 - Protected Plant (national parks and protected areas)
 - USGS Global Land Cover
 - General climate data from Greater Mekong Subregion Information Portal
- **Analysis Applications (existing data):** Technical Potential, Economic Potential, RE Zones, Resilience and Risk, Electrification
- **Possible gaps:** Local datasets could be useful and would ultimately impact the available supply of renewable energy.

Market and Demand

- **Highlights:** Electricity price and consumption information from Electricity Authority of Cambodia and Intelligent Energy Systems report
- **Analysis Applications (existing data):** Economic potential
- **Possible gaps:** Hourly load data is recommended to be able to conduct grid integration studies

Transportation

- **Highlights:** Publicly available transportation data is available through crowd-sourced data on OpenStreetMap (OSM). Unfortunately, the completeness and accuracy is unknown and thus requires validation.
- **Analysis Applications (existing data):** Economic Potential
- **Possible gaps:** More detailed transportation data is important for understanding nuances of RE construction and deployment (among other things).

Administrative / Other

- **Highlights:** Rich database from which to draw the “other” category. Population density can serve as load proxy and is also important for understanding potential development barriers or for understanding populations at risk of natural hazard events
- **Analysis Applications (existing data):** Technical Potential, Economic Potential, REZ Zones, Grid Integration Studies, Distributed Solar PV, Resiliency and Risk, Electrification
- **Possible gaps:** To enable detailed distributed Solar PV estimates and analysis, creation of building inventory “microdata” is recommended.

Summary

- Based on our assessment, Cambodia has sufficient data to conduct many types of RE analysis
- Beginning the process of developing *hourly* wind, solar, and load GIS datasets would enable detailed analysis of RE potential, including:
 - Custom Generator modeling
 - Distributed rooftop PV assessment
 - Grid integration studies

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