Renewable Energy Zones for Balancing Siting Trade-offs in India

Multi-criteria Analysis for Planning Renewable Energy

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LAWRENCE BERKELEY NATIONAL LABORATORY | MAR 25, 2017

Summary

Our study has two parts:

We apply the Multi-criteria Analysis for Planning Renewable Energy (MapRE) framework to identify and create wind, solar photovoltaic, and concentrated solar power zones in India, and create tools, maps and geospatial data for prioritizing these zones.

We then provide specific insights into India's renewable energy resources, opportunities for their sustainable development, and potential constraints to their development.

The Gap

- Lack of high quality public data and information essential for scaling up RE development.

- Most forms of public information (e.g. RE resource maps) are inadequate as planning tools.

- Most of these forms are also static (not updatable, not interactive)

- Large information asymmetry between policymakers and project developers.

- Existing tools do not incorporate multiple criteria essential for sustainable development of RE (e.g. economic, social, and environmental criteria)

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Multi-criteria Analysis for Planning Renewable Energy (MapRE)
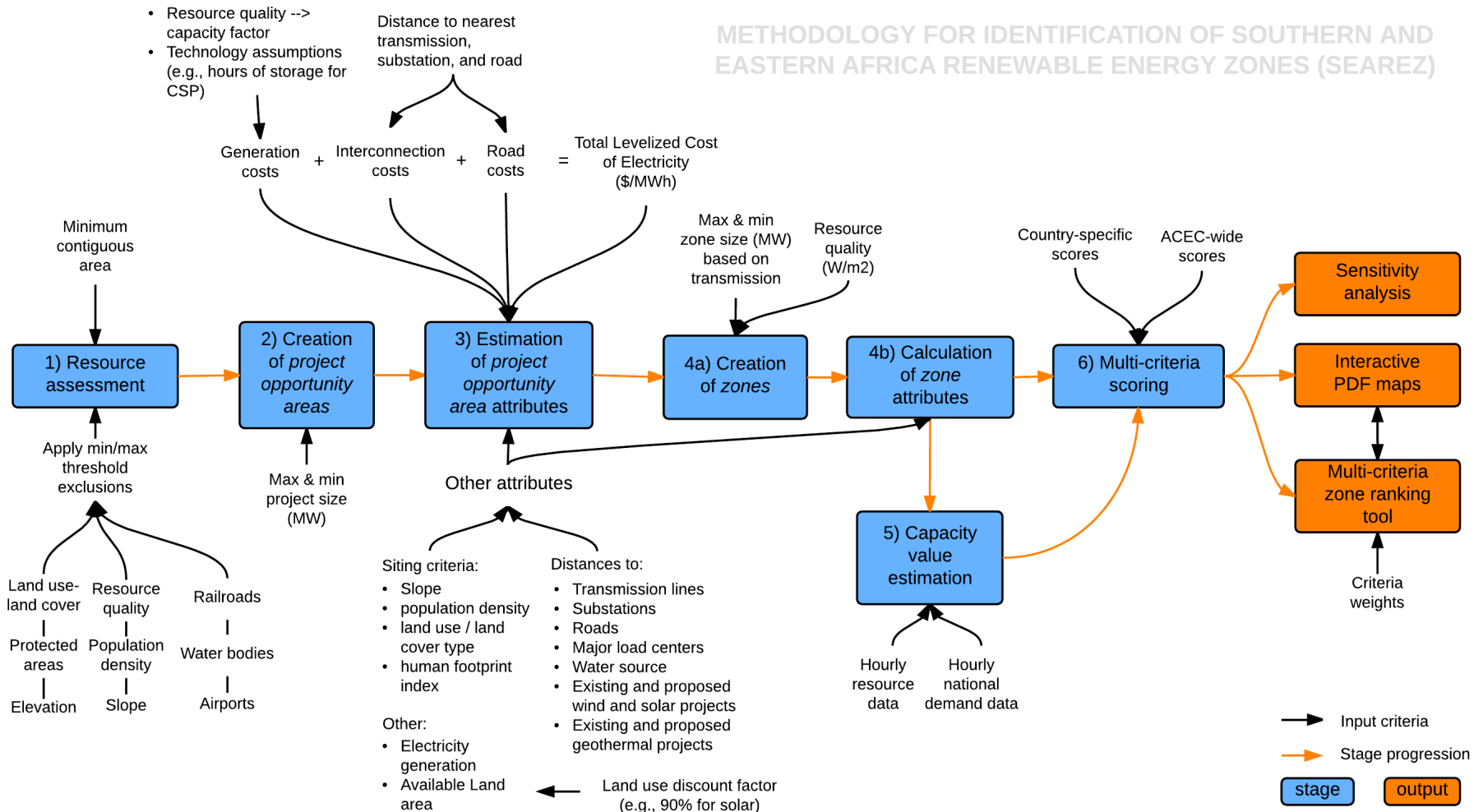
A Geospatial and Energy Economics Analysis Platform to:

- Identify cost-effective, environmentally sustainable, and socially-equitable renewable energy (RE) zones.

- Inform long-term planning of transmission and other infrastructure for RE development.

- Provide a platform to store, update, visualize, and interact with information essential for RE planning through a stakeholder process.

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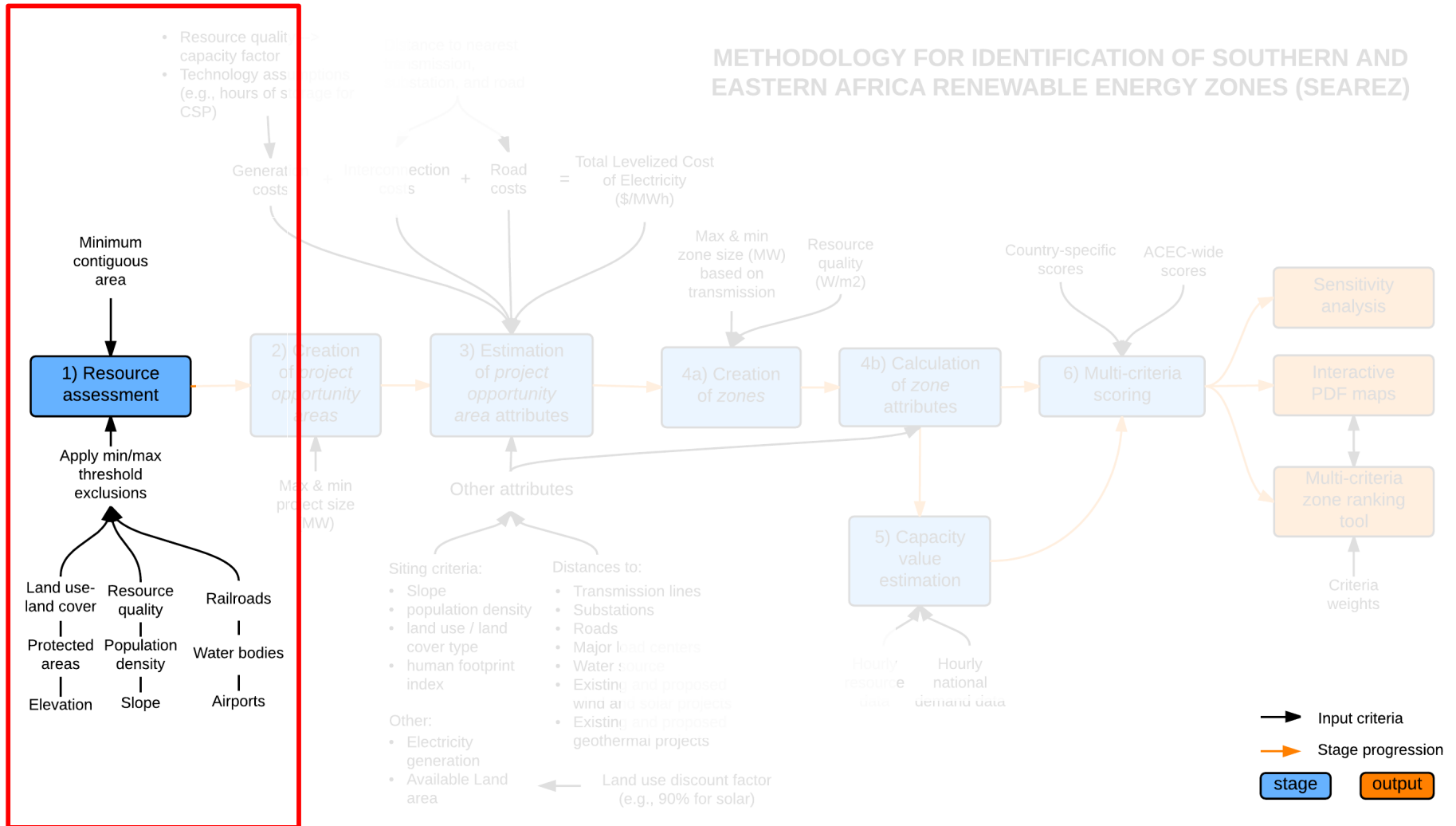Lawrence Berkeley National Laboratory

RE zoning study in the larger context
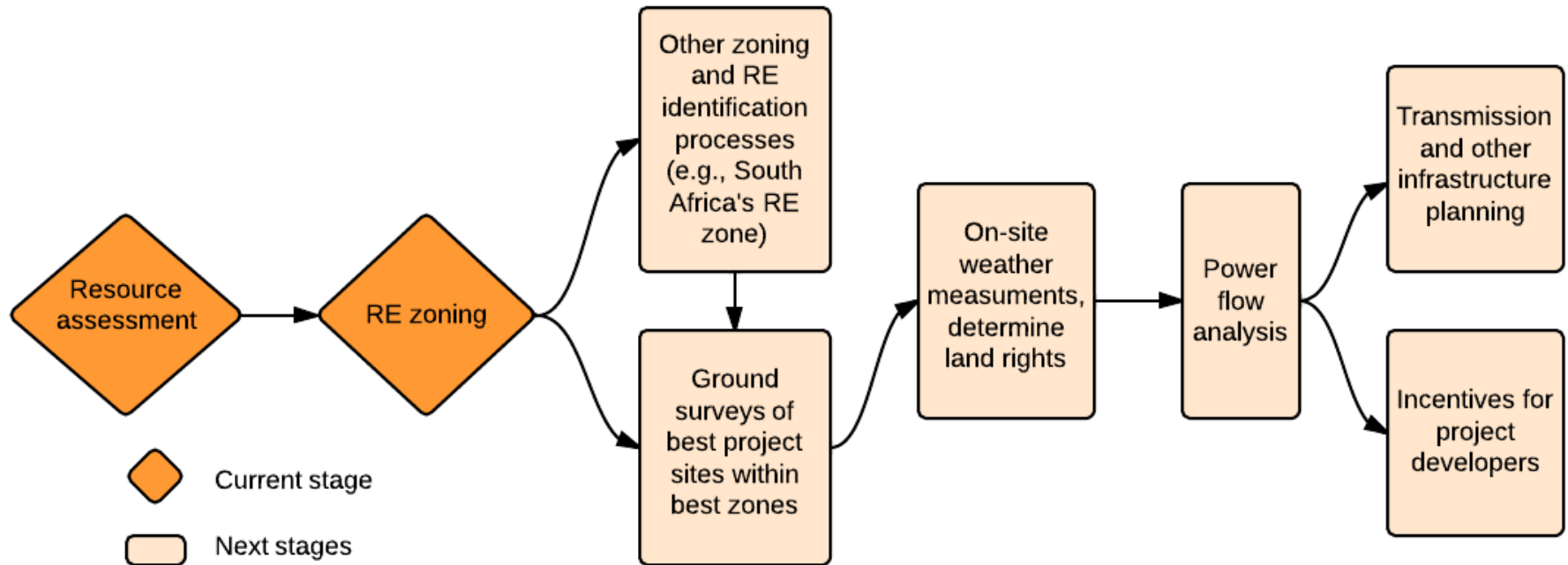
MapRE Methodology

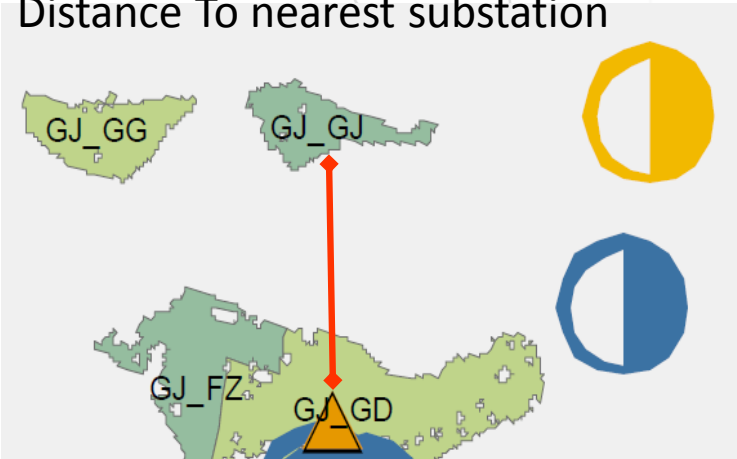
METHODOLOGY FOR IDENTIFICATION OF SOUTHERN AND EASTERN AFRICA RENEWABLE ENERGY ZONES (SEAREZ)

- Resource quality --> capacity factor
- Technology assumptions (e.g., hours of storage for CSP)

Distance to nearest transmission, substation, and road

Generation costs + Interconnection costs + Road costs = Total Levelized Cost of Electricity ($/MWh)

Minimum contiguous area

Max & min zone size (MW) based on transmission

Resource quality (W/m2)

Country-specific scores

ACEC-wide scores

1) Resource assessment → 2) Creation of *project opportunity areas* → 3) Estimation of *project opportunity area* attributes → 4a) Creation of *zones* → 4b) Calculation of *zone* attributes → 6) Multi-criteria scoring

Sensitivity analysis

Interactive PDF maps

Multi-criteria zone ranking tool

Apply min/max threshold exclusions

Max & min project size (MW)

Other attributes

5) Capacity value estimation

Criteria weights

Land use-land cover

Resource quality

Railroads

Protected areas

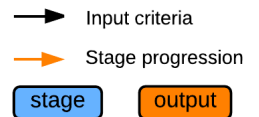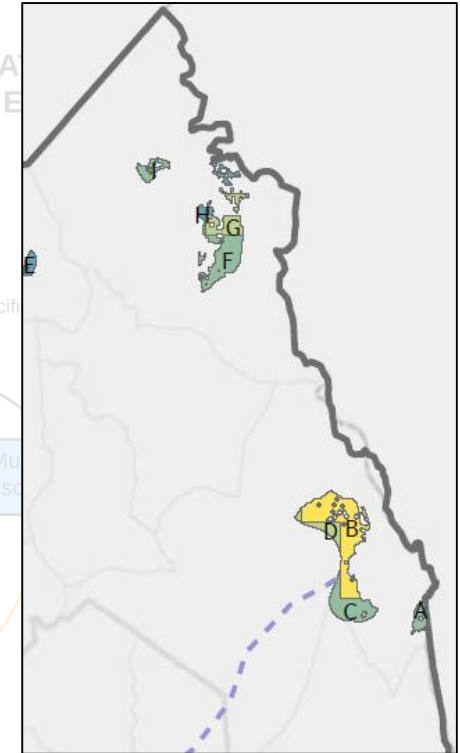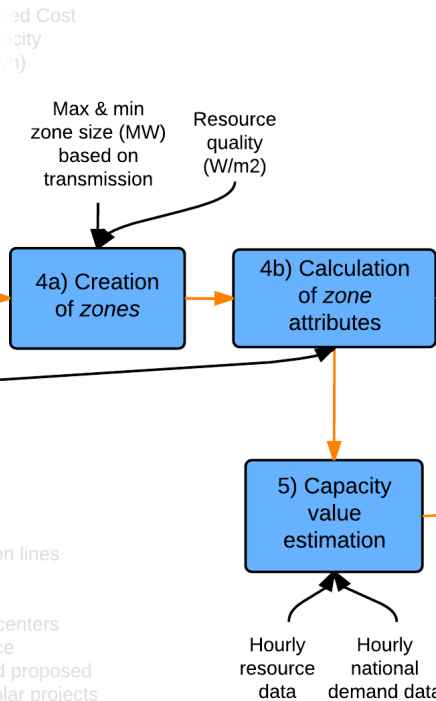Population density

Water bodies

Elevation

Slope

Airports

Siting criteria:
- Slope
- population density
- land use / land cover type
- human footprint index

Other:
- Electricity generation
- Available Land area

Distances to:
- Transmission lines
- Substations
- Roads
- Major load centers
- Water source
- Existing and proposed wind and solar projects
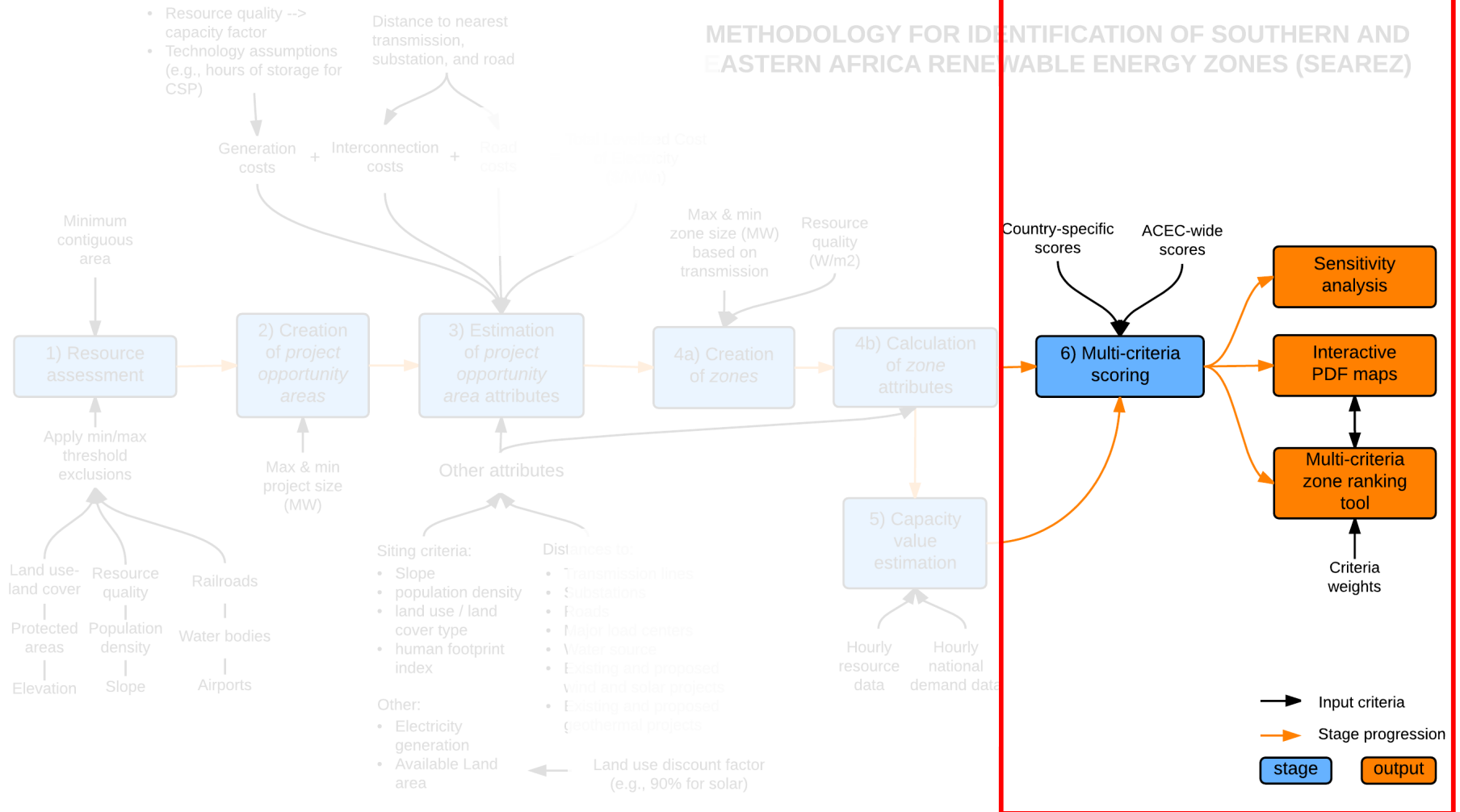- Existing and proposed geothermal projects

Hourly resource data

Hourly national demand data

Land use discount factor (e.g., 90% for solar)

Input criteria
Stage progression
stage   output

Renewable Energy Resource Assessment

Estimate attributes of Project Opportunity Areas
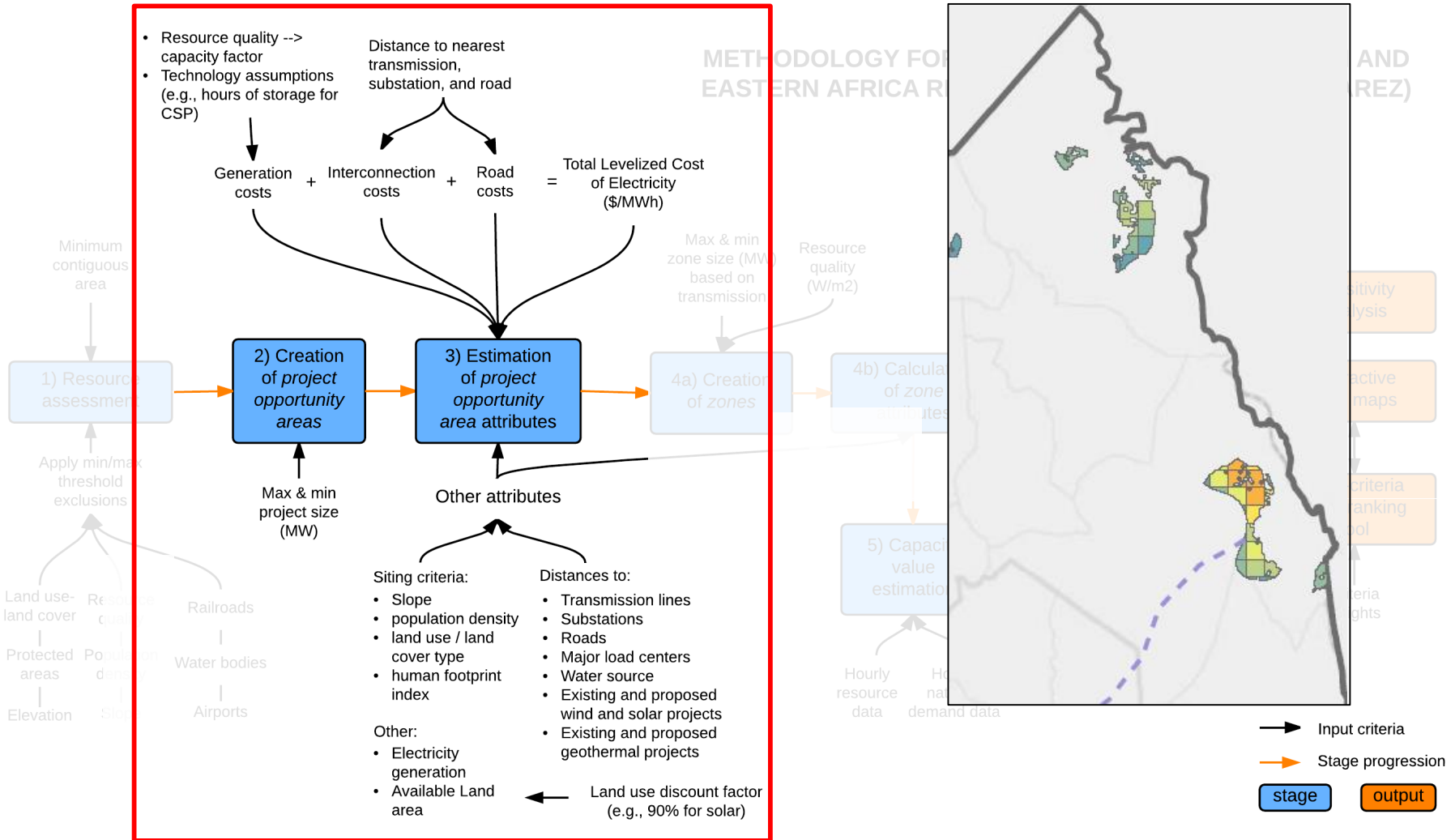
Create Zones and Aggregate Attributes

Score Zones and Create Outputs

METHODOLOGY FOR IDENTIFICATION OF SOUTHERN AND EASTERN AFRICA RENEWABLE ENERGY ZONES (SEAREZ)
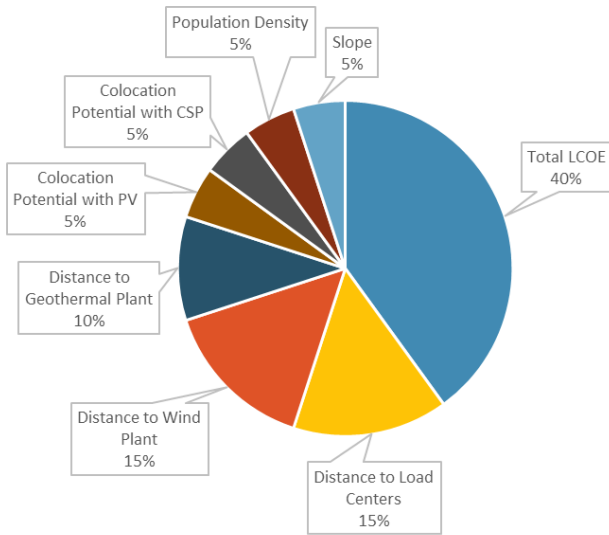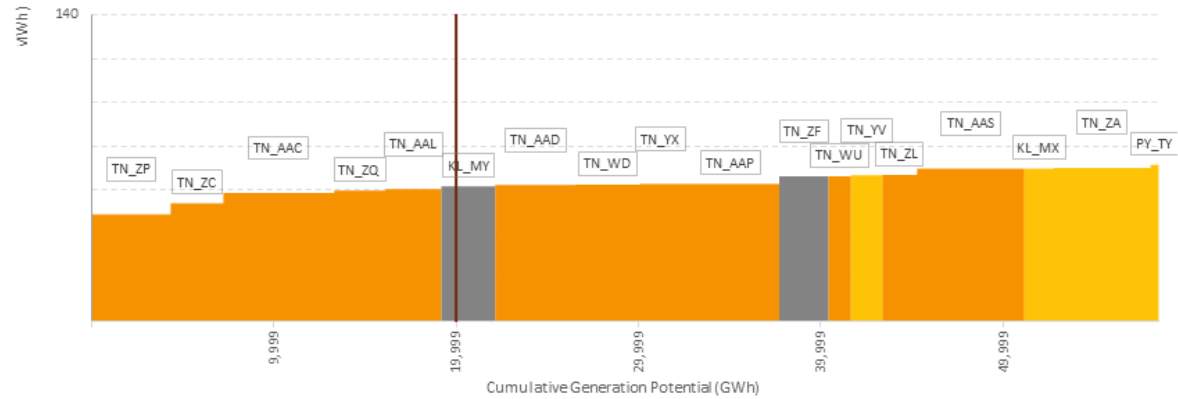
Zone ranking and supply curves

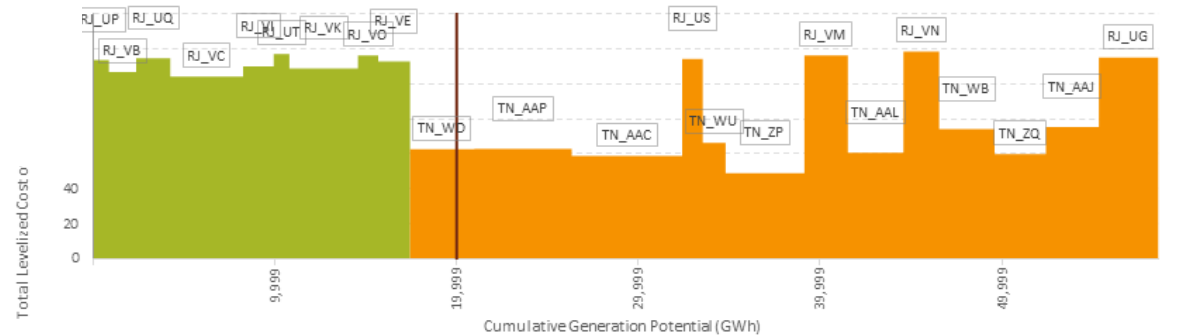## Microsoft Excel®-based tool enables user-specified weighting and prioritization of RE zones

User-specified shares of weights (top) and supply curves sorted by cost (top right) and zone scores (bottom right)

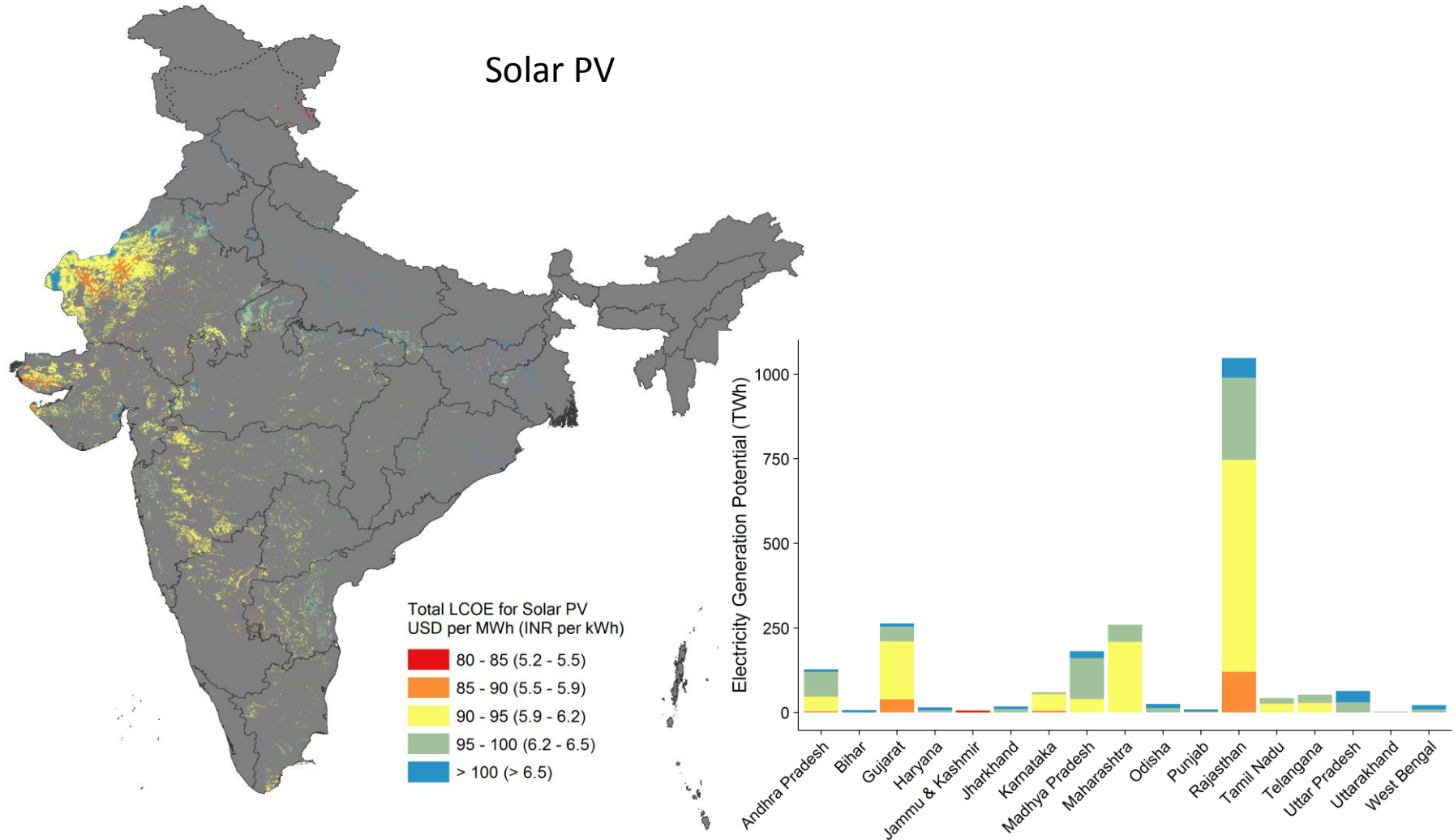# KEY RESULTS – Abundant RE resources

High quality wind and solar potential is concentrated in western and southern states
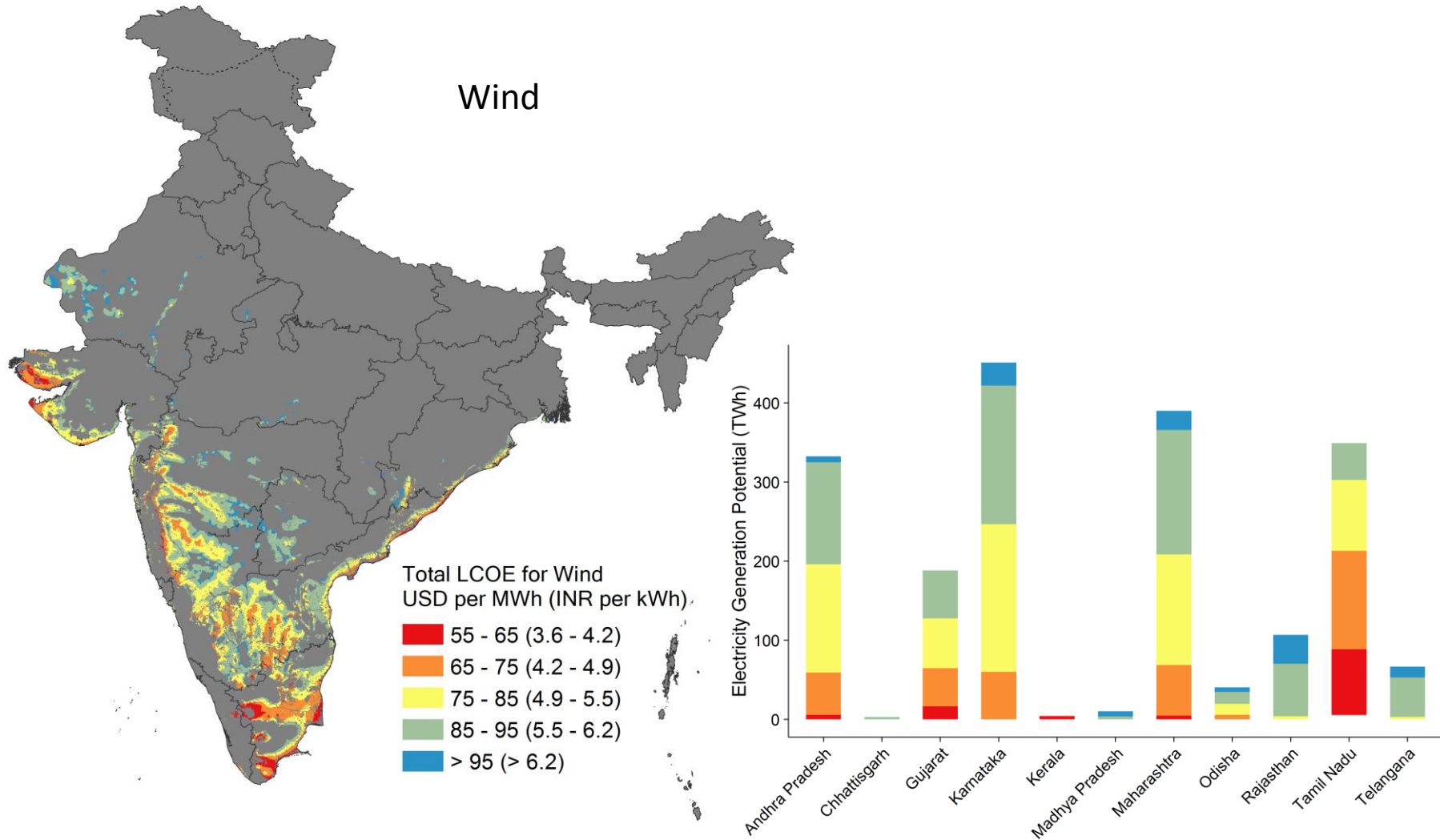
KEY RESULTS – Abundant RE resources

Solar PV costs are comparable to wind. Potential limited by land availability.

Solar PV

Total LCOE for Solar PV
USD per MWh (INR per kWh)
- 80 - 85 (5.2 - 5.5)
- 85 - 90 (5.5 - 5.9)
- 90 - 95 (5.9 - 6.2)
- 95 - 100 (6.2 - 6.5)
- > 100 (> 6.5)

KEY RESULTS – Abundant RE resources

Solar CSP is significantly more expensive than both wind and solar PV, and has limited potential

Concentrated Solar Power

Total LCOE for Solar CSP
USD per MWh (INR per kWh)

- 150 - 170 (9.8 - 11.1)
- 170 - 180 (11.1 - 11.7)
- 180 - 190 (11.7 - 12.4)
- 190 - 200 (12.4 - 13.0)
- > 200 (> 13.0)
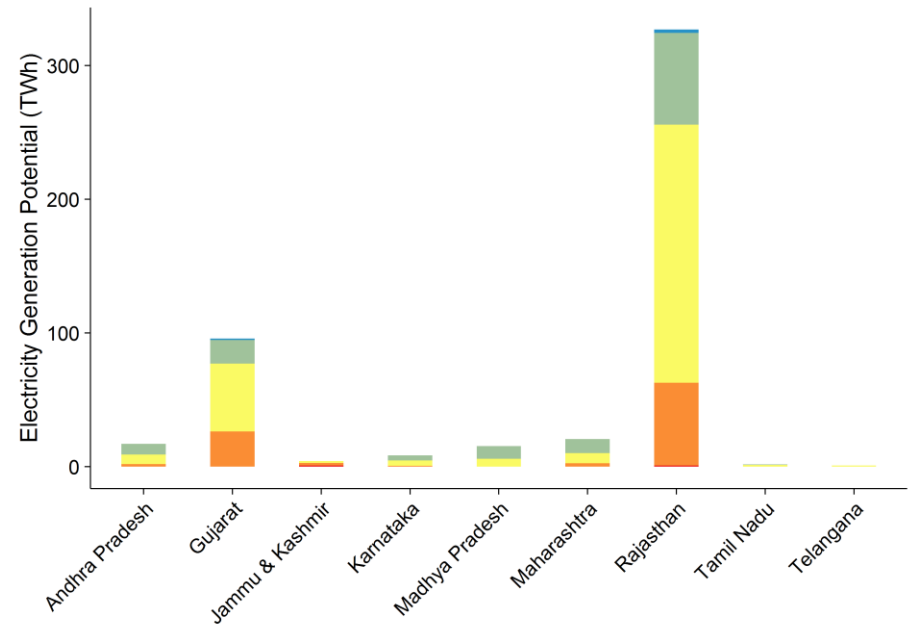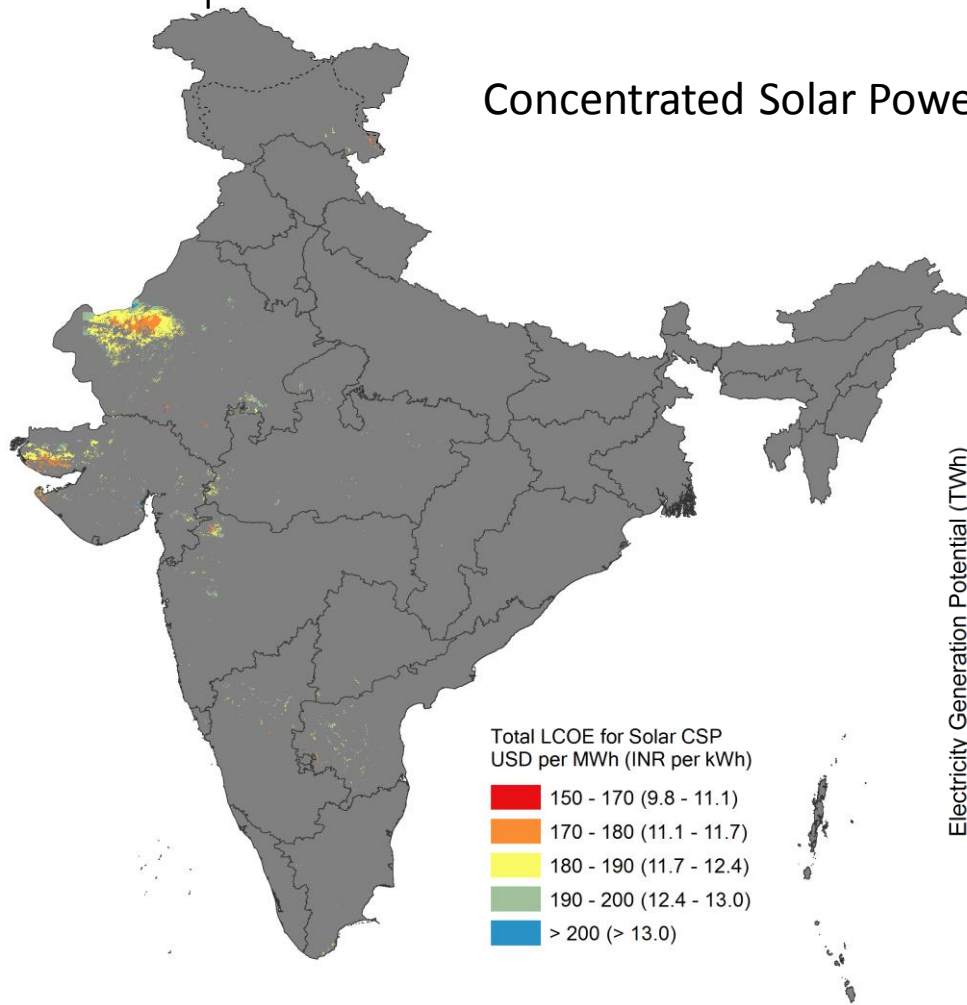
KEY RESULTS – Cost of wind and solar

Levelized cost of energy (LCOE) for wind and solar PV are comparable.

Distribution of LCOEs indicates greater variability in wind and CSP resource quality as compare with solar PV.

CSP resources may cost twice as much as wind or solar PV.

Inputs to LCOE estimates assume Central Electricity Regulatory Commission 2016 norms

KEY RESULTS – Pre-planning Transmission

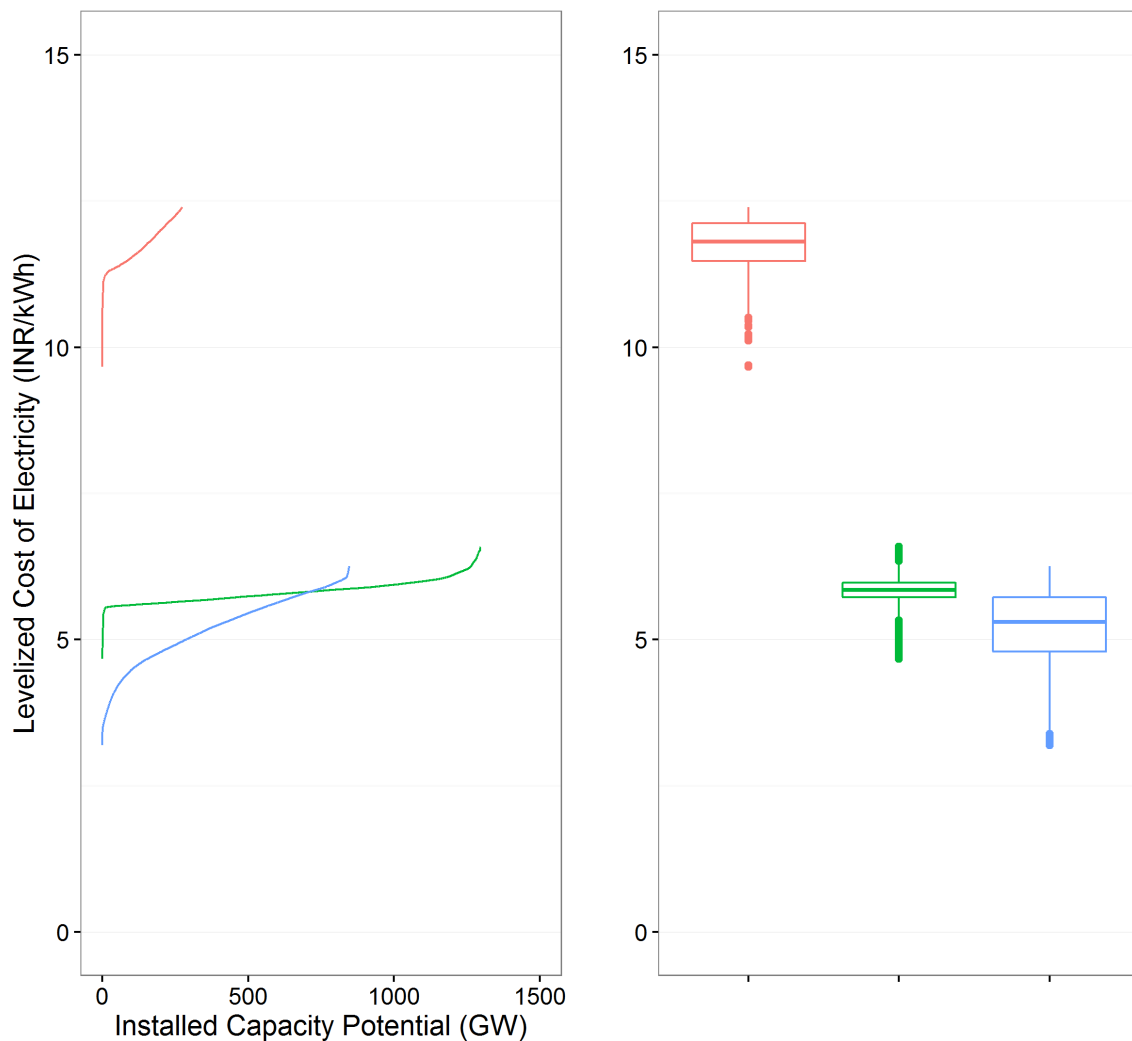Pre-planning transmission by identifying zones with high resource quality (low cost) and farthest from high voltage transmission network can enable development and evacuation

Wind Zones

Distance from 220kV+ Substation > 25 km

Distance to Substation > 25 km
Generation LCOE for Wind
USD per MWh (Rs per kWh)

■	55 - 65 (3.6 - 4.2)
■	65 - 75 (4.2 - 4.9)
■	75 - 85 (4.9 - 5.5)
■	85 - 95 (5.5 - 6.2)
■	> 95 (> 6.2)

Distance to Substation <= 25 km

■	

▲   Substation >= 220 kV
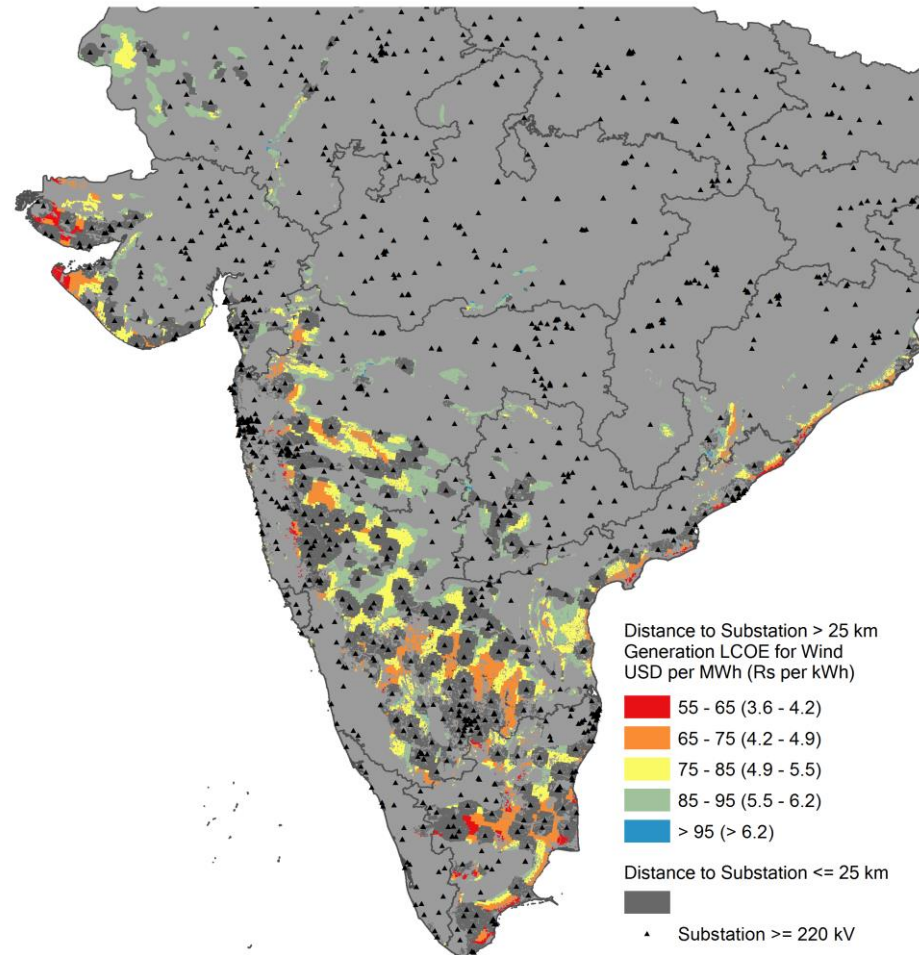
KEY RESULTS – Wind on Agricultural lands

84% of wind resources are on agricultural land (as identified using NRSC-ISRO data). Land leasing and revenue sharing may enable socially equitable development.

Wind resources on
- Non-agricultural land
- Agricultural land
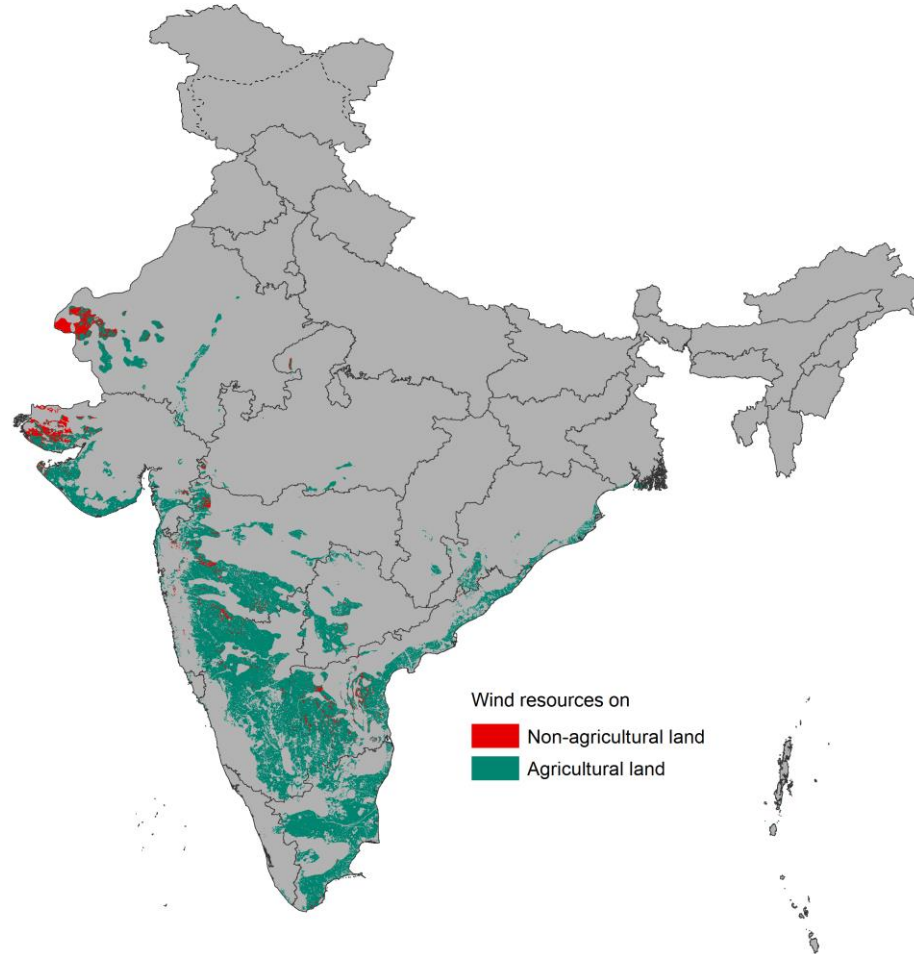
KEY RESULTS – Capacity Value

Prioritizing wind zones with higher capacity value and not just annual average capacity factor may provide more benefits to the overall system

Capacity Factor
(Annual Average)

Capacity Value*
(top 10% peak hours)

Capacity Factor
[Annual Average]

- 21% - 25%
- 25% - 30%
- 30% - 35%
- 35% - 40%
- > 40%

Capacity Value
[Capacity Factor during top 10% peak hours]

- 21% - 25%
- 25% - 30%
- 30% - 35%
- 35% - 40%
- > 40%
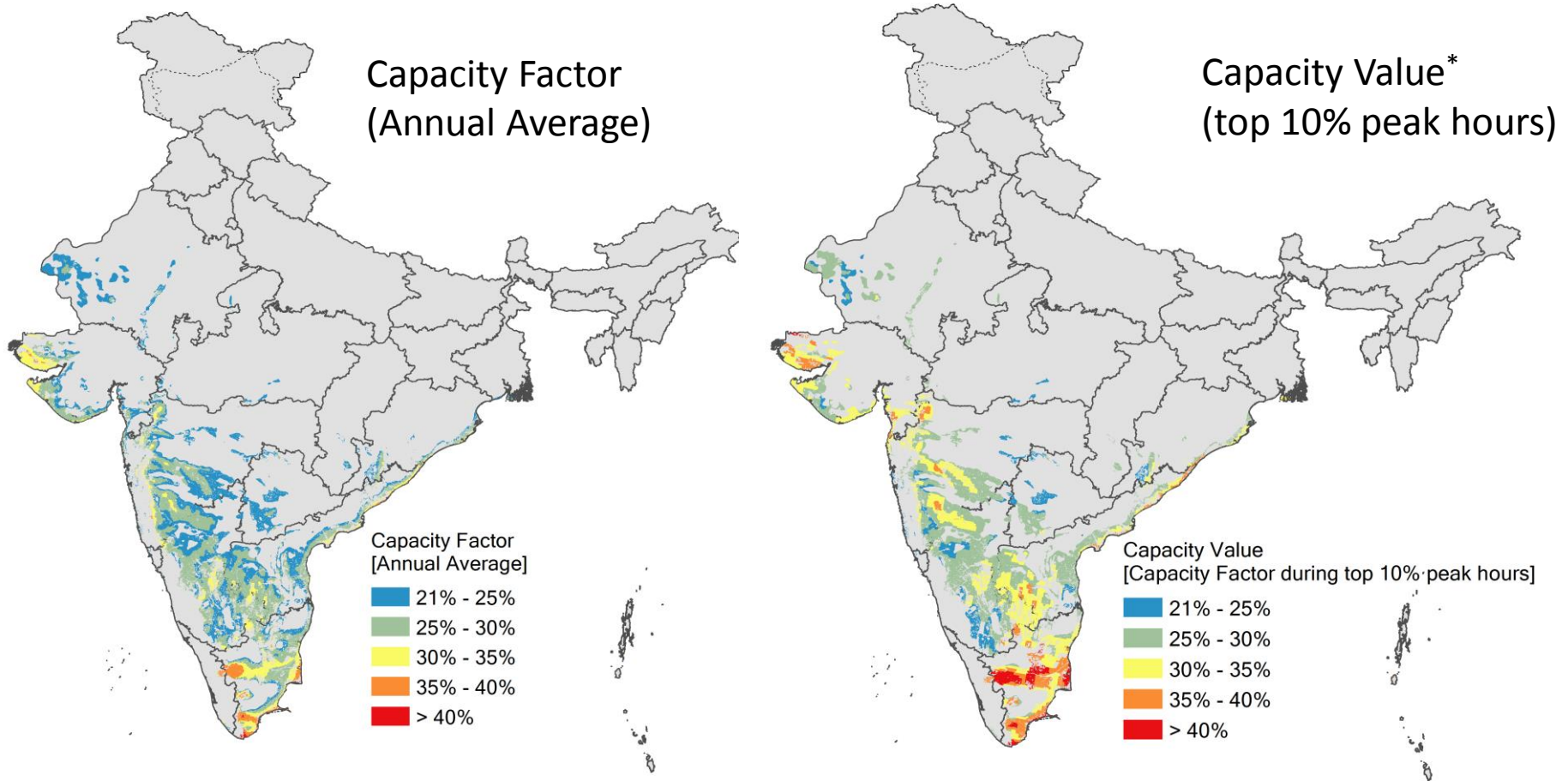
*Capacity value metric determines how well wind temporal profiles match load

PRODUCTS & OUTPUTS

1

Anyone

REPORT

- Detailed assumptions and methods
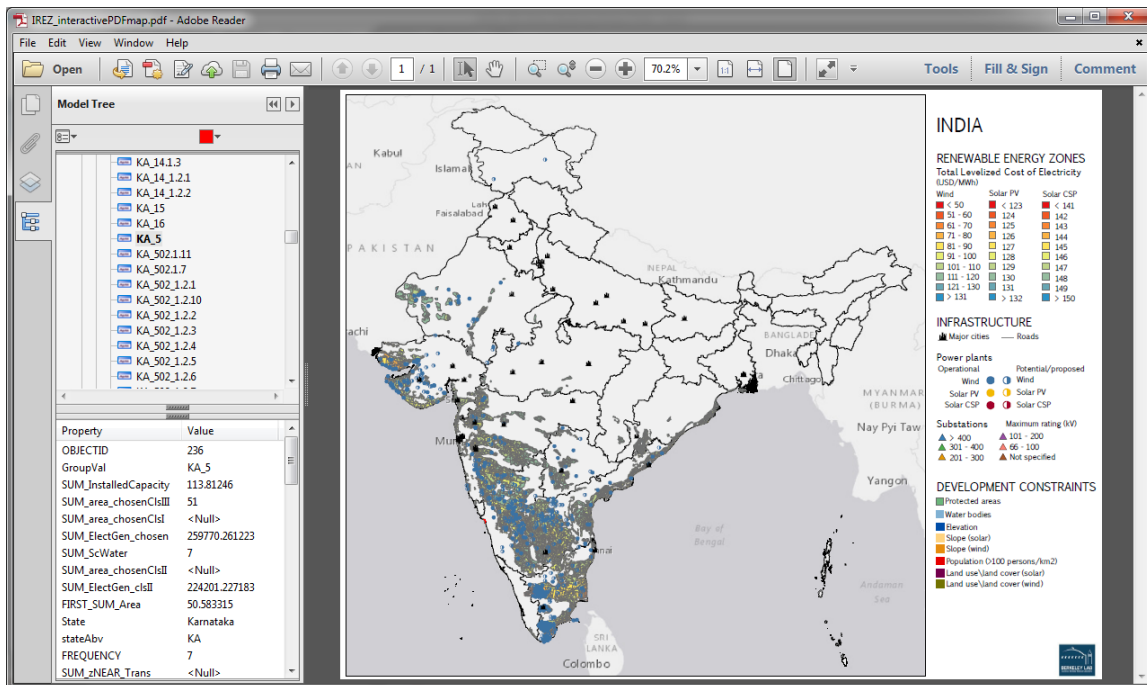
PRODUCTS & OUTPUTS

1

Anyone

REPORT
- Detailed assumptions and methods

2

Anyone

INTER-ACTIVE PDF MAPS
- Visualize data and access embedded attributes of RE zones.

PRODUCTS & OUTPUTS

1 Anyone

REPORT
- Detailed assumptions and methods

2 Anyone

INTER-ACTIVE PDF MAPS
- Visualize data and access embedded attributes of RE zones.

3 Anyone with Microsoft Office

ZONE RANKING TOOL
- Data interaction and stakeholder inputs

ZONE RANKING SORTED BY LEVELIZED COST OF ELECTRICITY

ZONE RANKING SORTED BY ZONE SCORE

Total LCOE 40%

Distance to Load Centers 15%

Distance to Wind Plant 15%

Distance to Geothermal Plant 10%

Colocation Potential with PV 5%

Colocation Potential with CSP 5%

Population Density 5%

Slope 5%

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1

Anyone

REPORT
- Detailed assumptions and methods
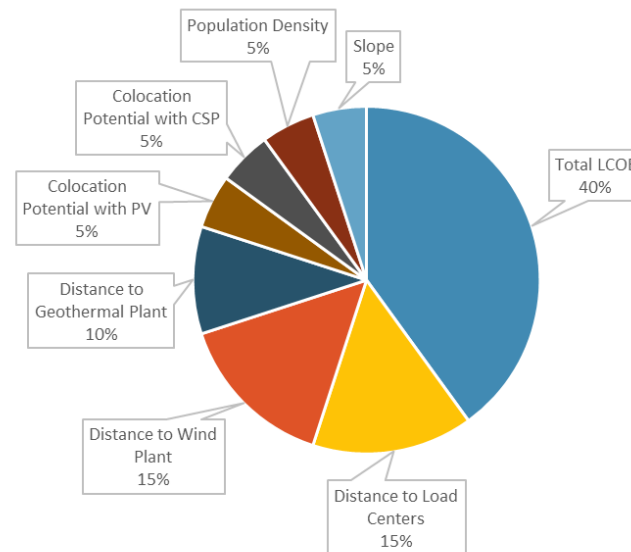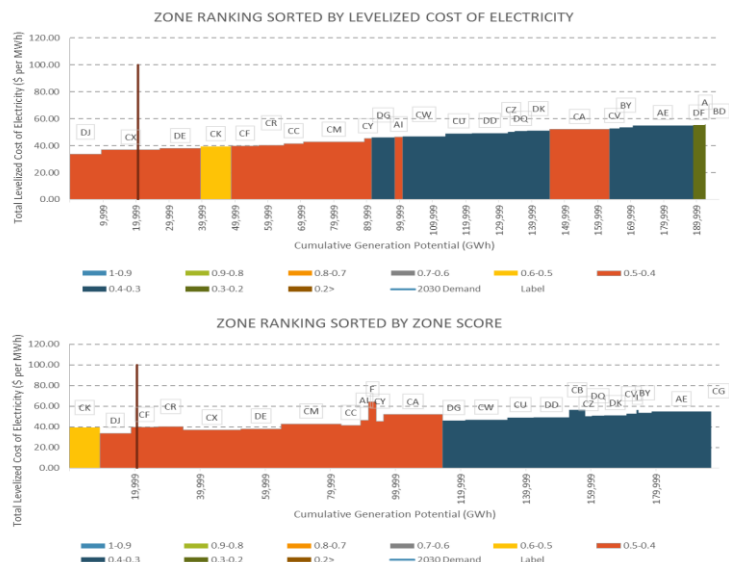
2

Anyone

INTER-ACTIVE PDF MAPS
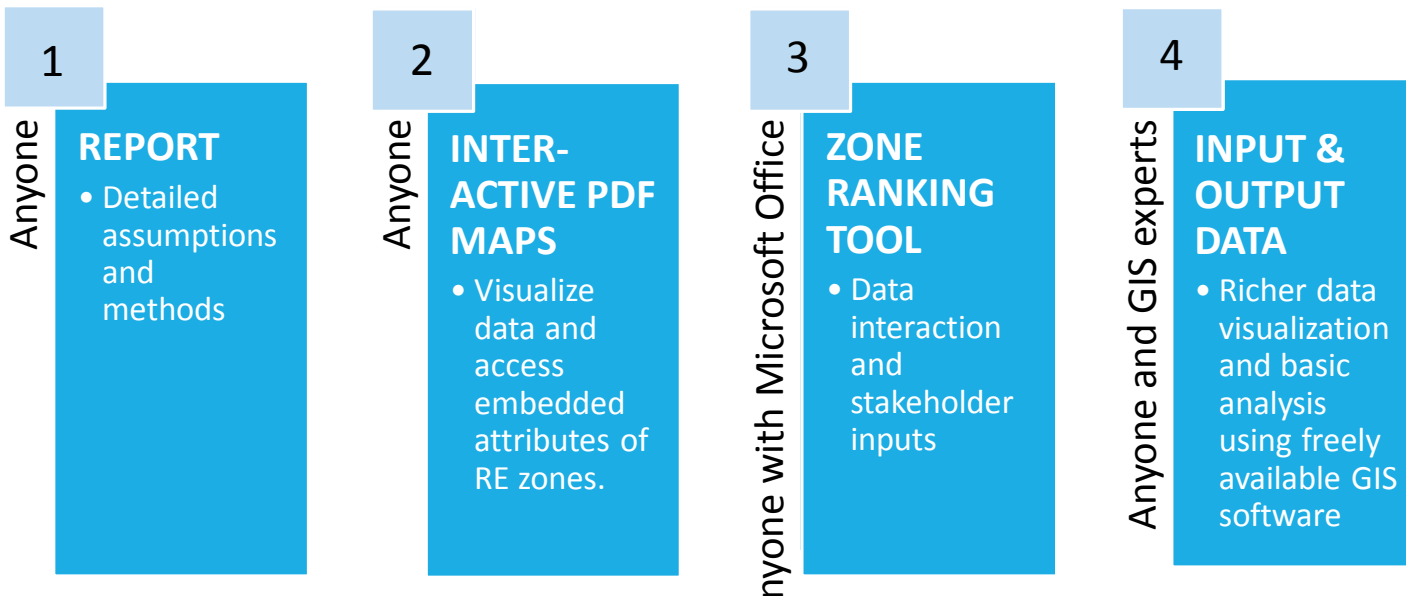- Visualize data and access embedded attributes of RE zones.

3

Anyone with Microsoft Office

ZONE RANKING TOOL
- Data interaction and stakeholder inputs

4

Anyone and GIS experts

INPUT & OUTPUT DATA
- Richer data visualization and basic analysis using freely available GIS software

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MAP RE   Africa   India   Spatial Data   GIS Tools   News   Contact

Spatial Data

UPDATED SPREADSHEET TOOLS

Data Sorted by Regional Energy Zone

Click on any of the buttons in the table below to download spatial data documents.

	Interactive PDF	Excel Supply Curves	Inputs	Outputs
IREZ				
India				Geospatial Outputs ▾
SEAREZ				
East Africa Power Pool	Interactive PDF Map			
South Africa Power Pool	Interactive PDF Map			
Angola	Interactive PDF Map	Excel Supply Curve		Geospatial Outputs ▾
Botswana	Interactive PDF Map	Excel Supply Curve		Geospatial Outputs ▾

PRODUCTS & OUTPUTS

1

Anyone

REPORT
- Detailed assumptions and methods

2

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- Visualize data and access embedded attributes of RE zones.

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5

GIS experts

GIS TOOLS
- Proprietary GIS software (ArcGIS) required or proficiency in another GIS software

PRODUCTS & OUTPUTS

1 — Anyone

METHODS REPORT

- Detailed assumptions and methods

2 — Anyone

INTER-ACTIVE PDF MAPS

- Proprietary GIS software (ArcGIS) required or proficiency in another GIS software

3 — Anyone with Microsoft Office

ZONE RANKING TOOL

- Data interaction and stakeholder inputs

4 — Anyone and GIS experts
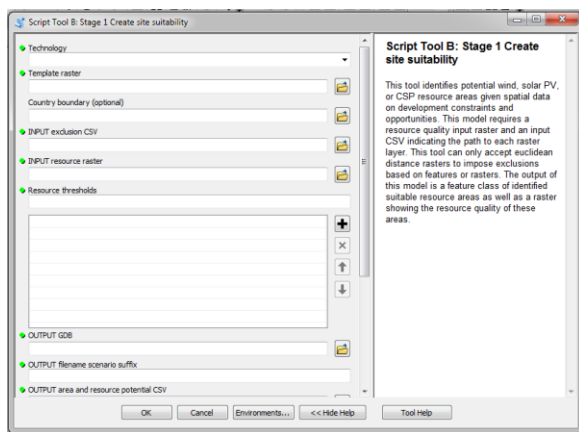
INPUT & OUTPUT DATA

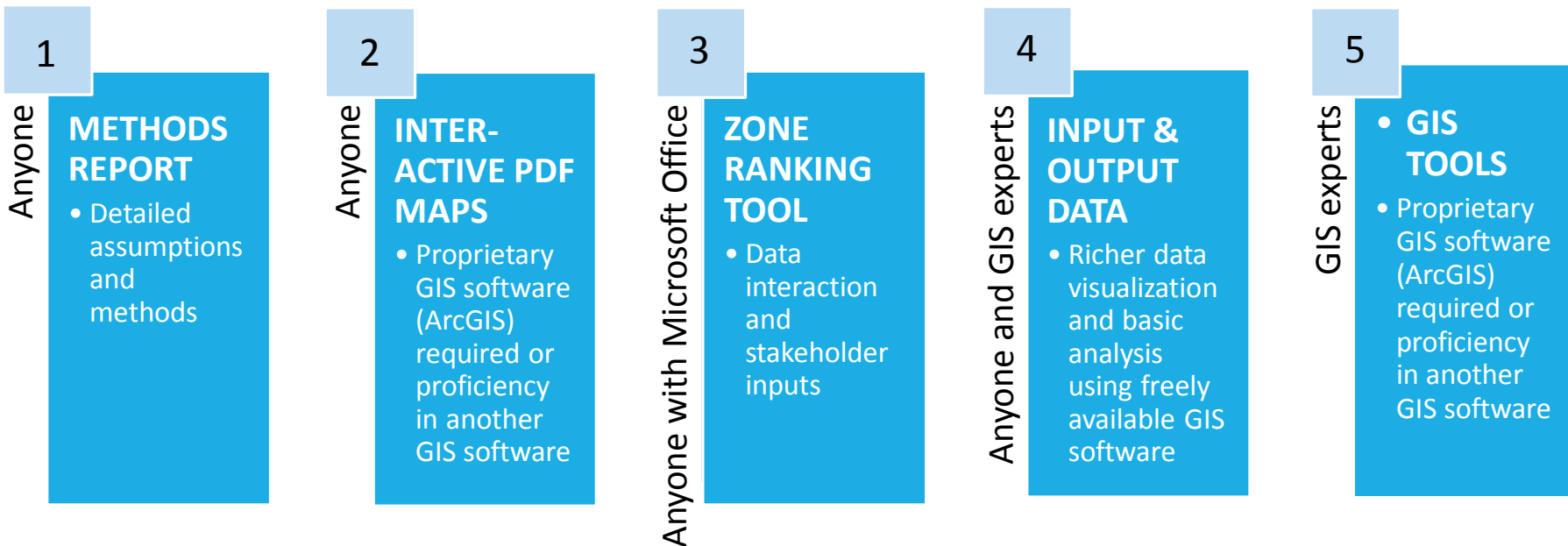- Richer data visualization and basic analysis using freely available GIS software

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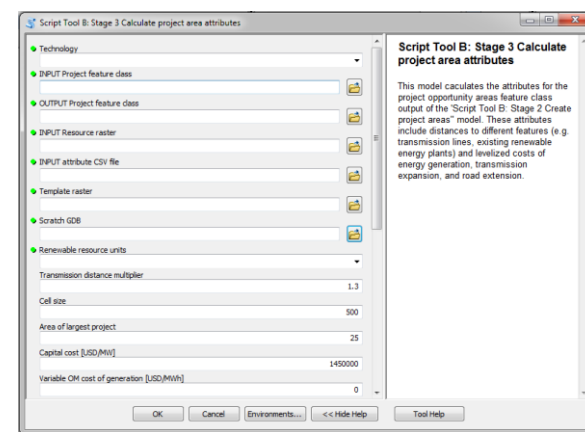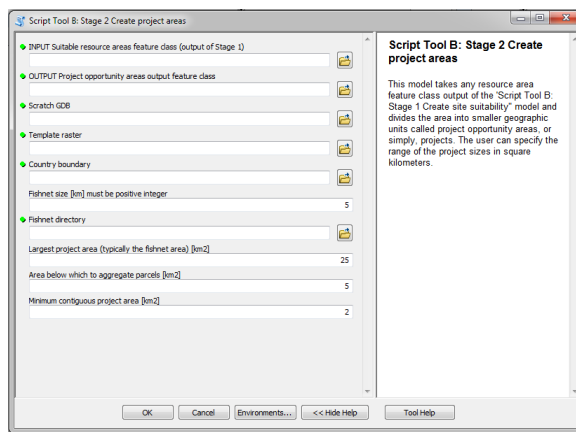
available at
mapre.lbl.gov

MORE INFO

WEBSITES FOR DOWNLOADING AND VIEWING DATA:

http://mapre.lbl.gov/

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