# Afghanistan Geospatial Analysis

## Multi-criteria Analysis for Renewable Energy Mapping and Valuation

WORLD BANK GROUP

# Identify areas suitable for solar and wind energy development

**Goal**

- Identify, quantify, and economically value high-quality potential renewable projects in Afghanistan
- Examine key siting constraints and opportunities

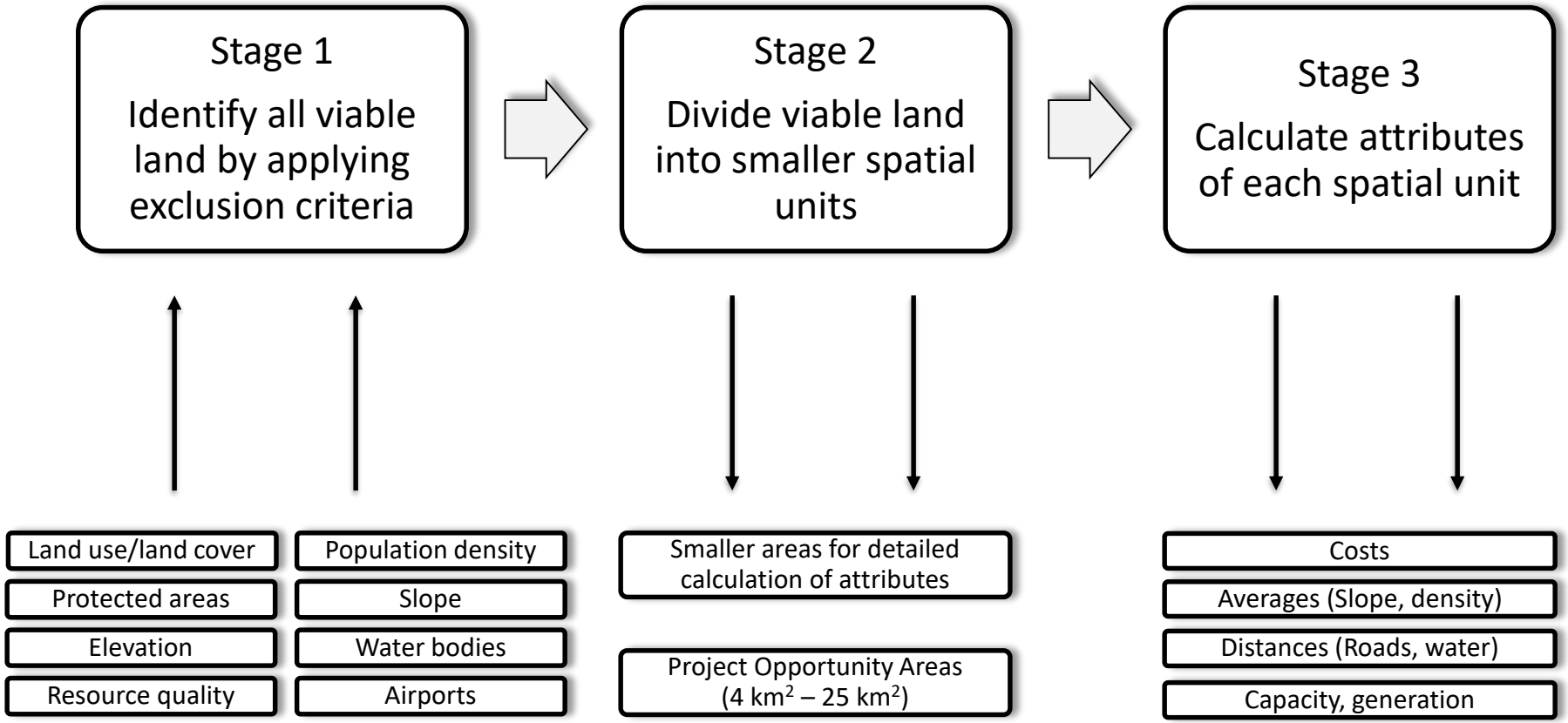
**Methodology**

- Analysis based on Geospatial Information systems
- Use of GIS scripts developed by Lawrence Berkeley National Laboratory
- Simulations using tentative assumptions, leading to preliminary results

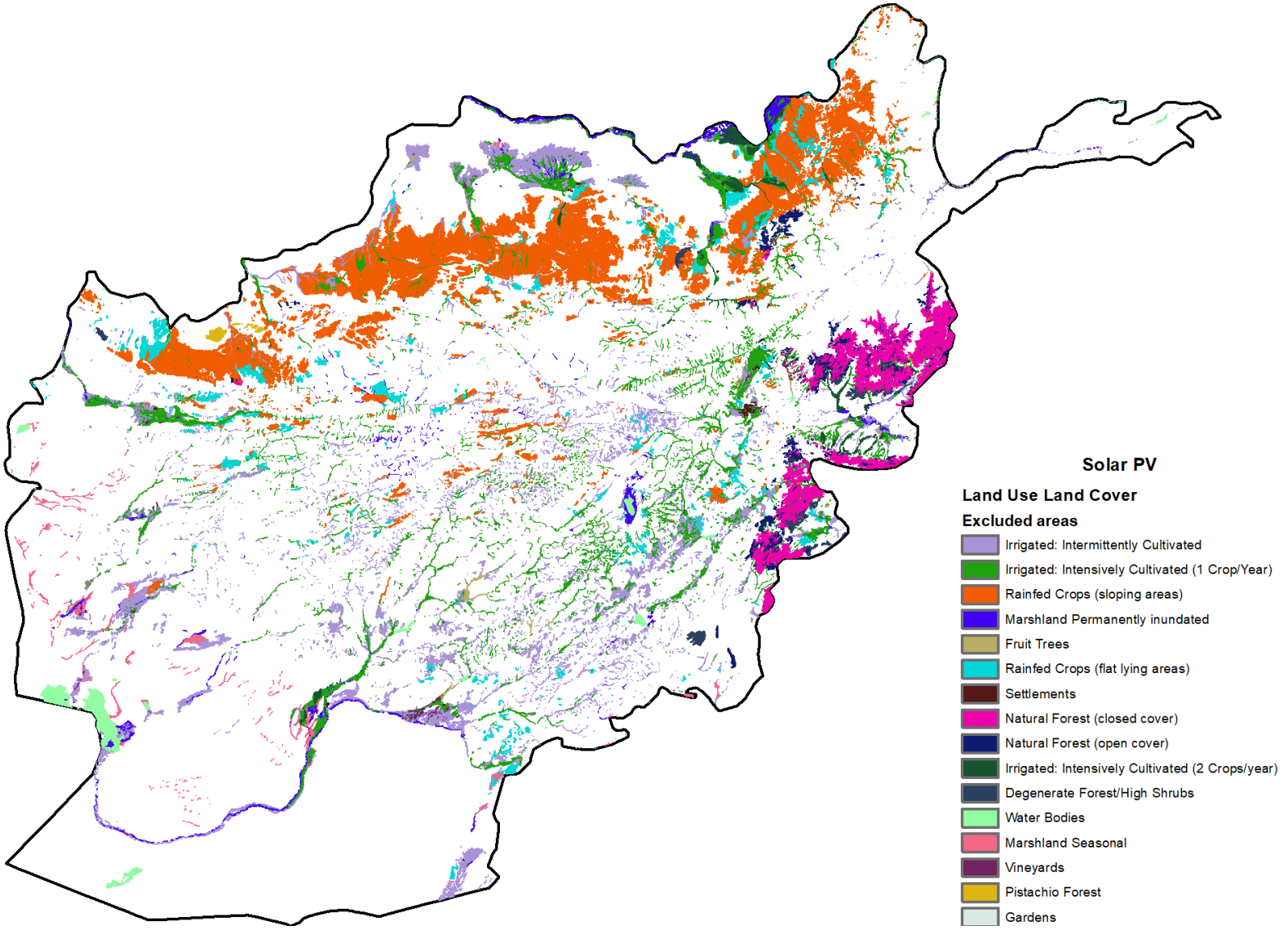
**Constraints: Flexibility**

- Scalable results
- Input data and assumptions defined by the user
- Quantification of errors

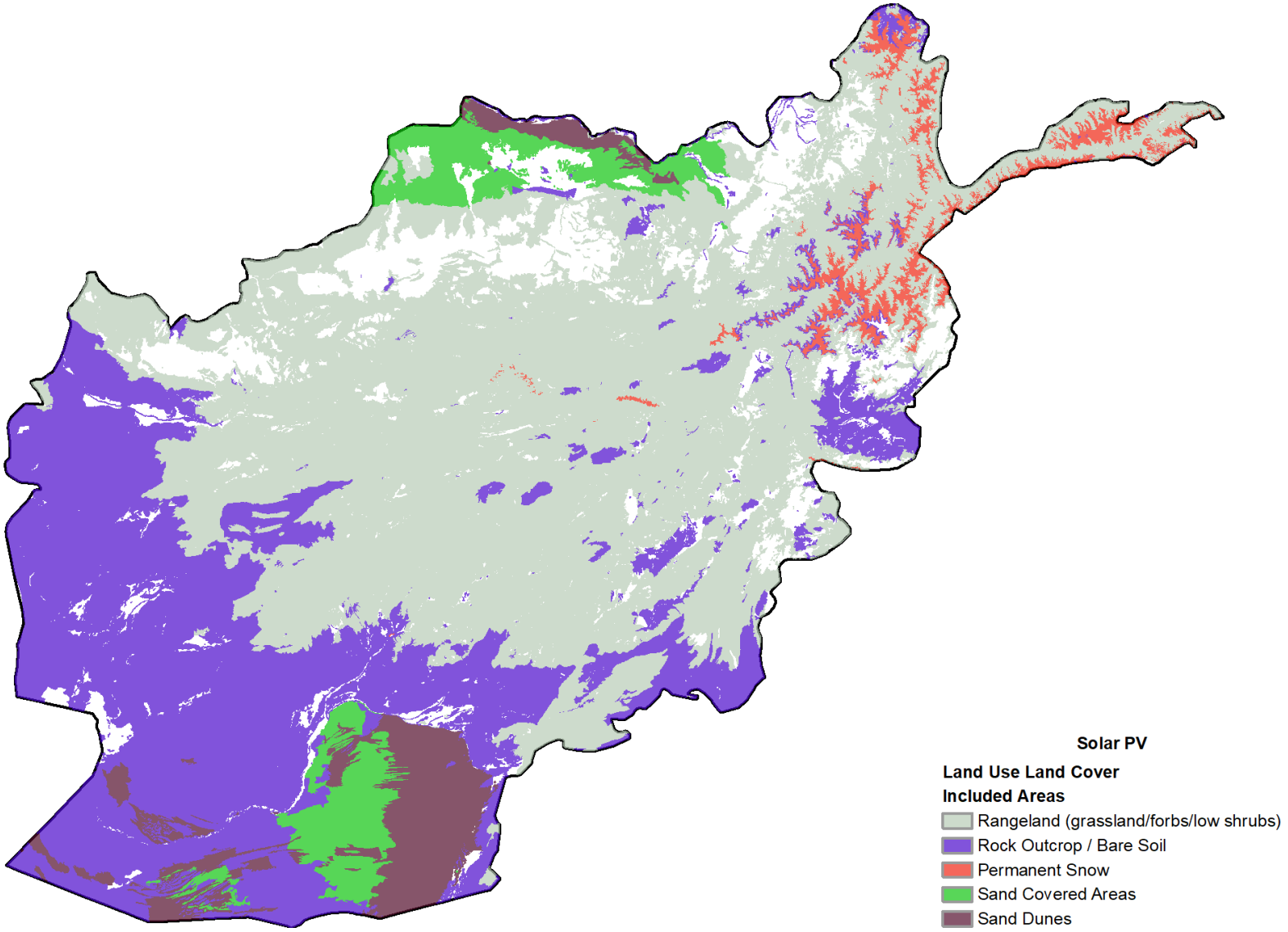
# Multi-criteria analysis



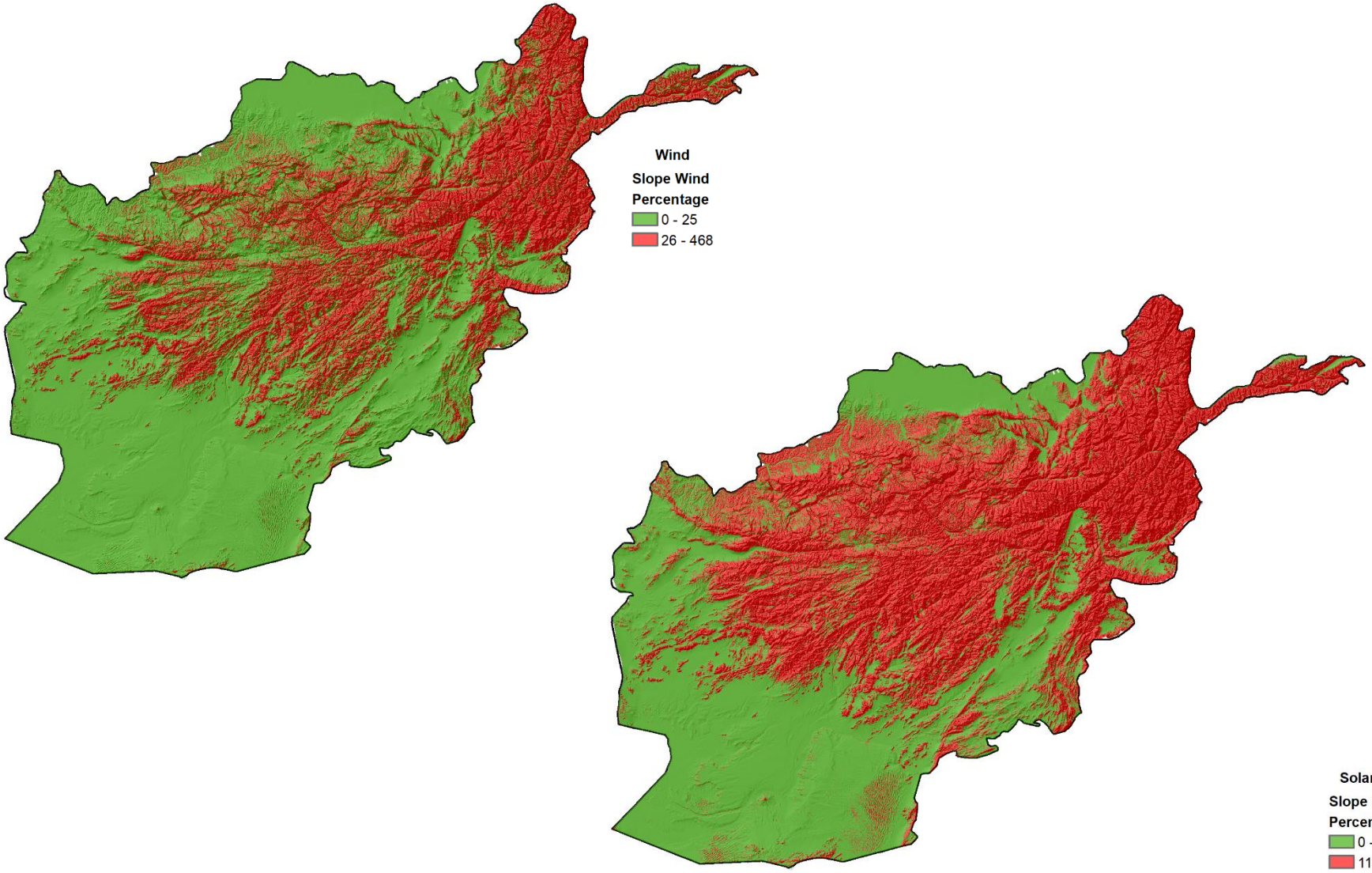
# Land Use/Land Cover excluded areas



# Land Use/Land Cover included areas



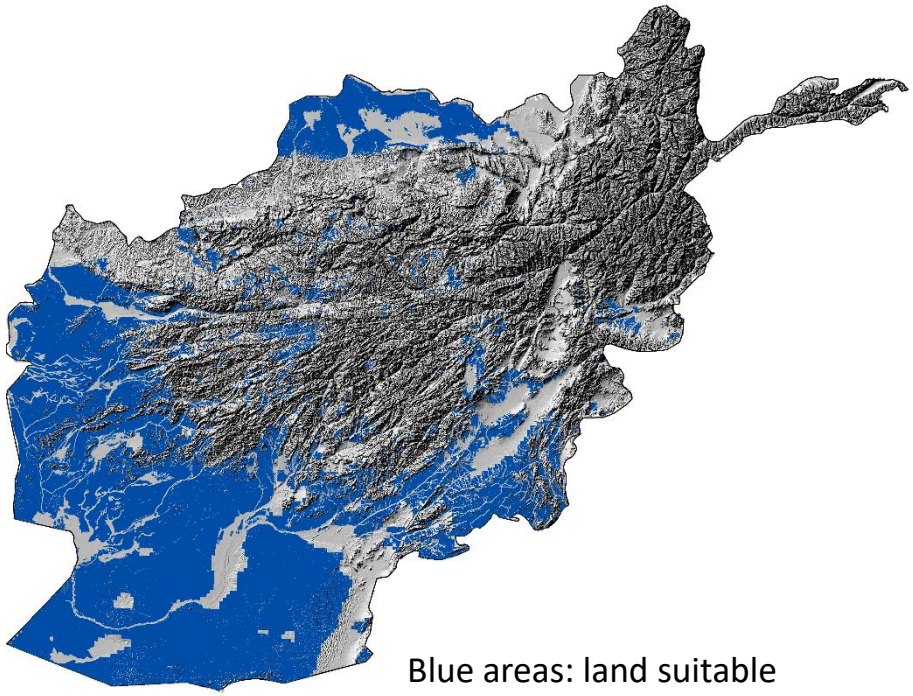
# Excluded sloping areas



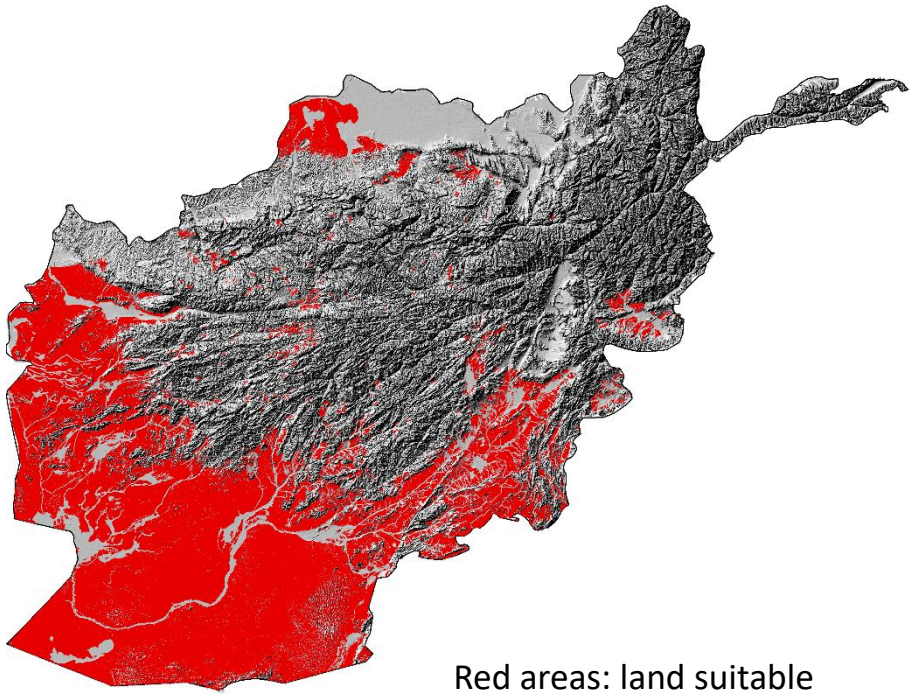
**Stage 1**

**Identify all viable land by applying exclusion criteria**

Final results for Wind and Solar PV technologies



Blue areas: land suitable for Wind development

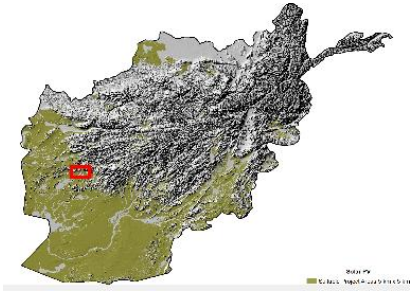


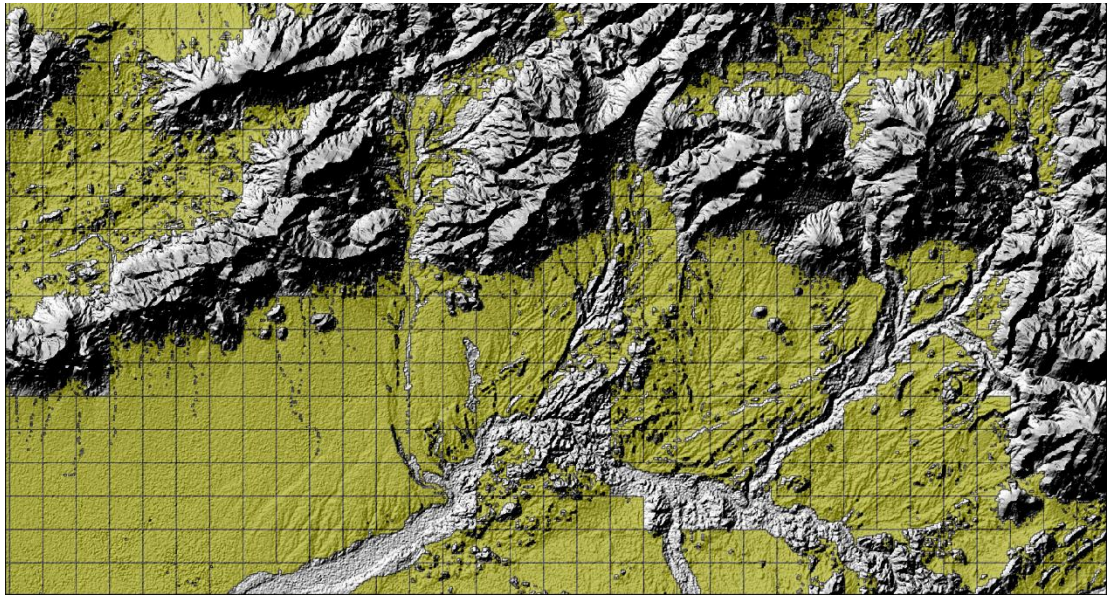
Red areas: land suitable for solar PV development

**Stage 2**

**Divide included areas into smaller spatial units**

In this stage, all land which met the inclusion criteria is divided into spatial units, or ‘Project Opportunity Areas’





Spatial units 2 km x 2 km

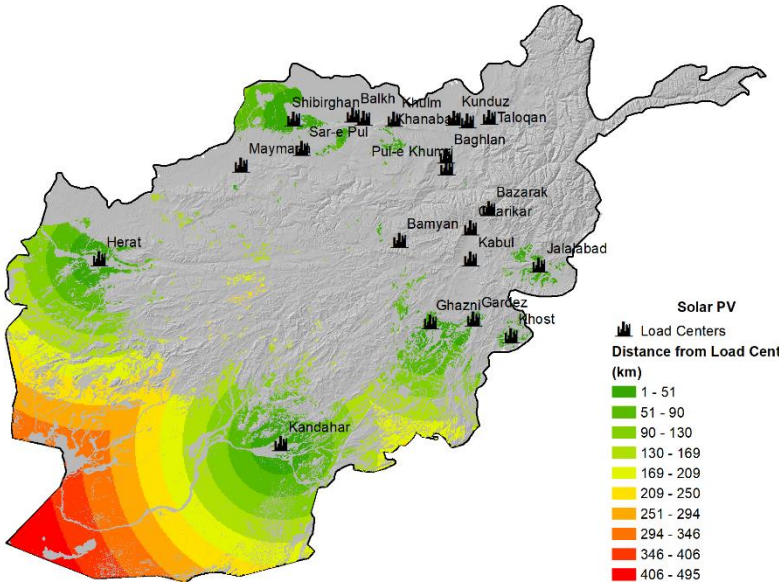
**Stage 3**

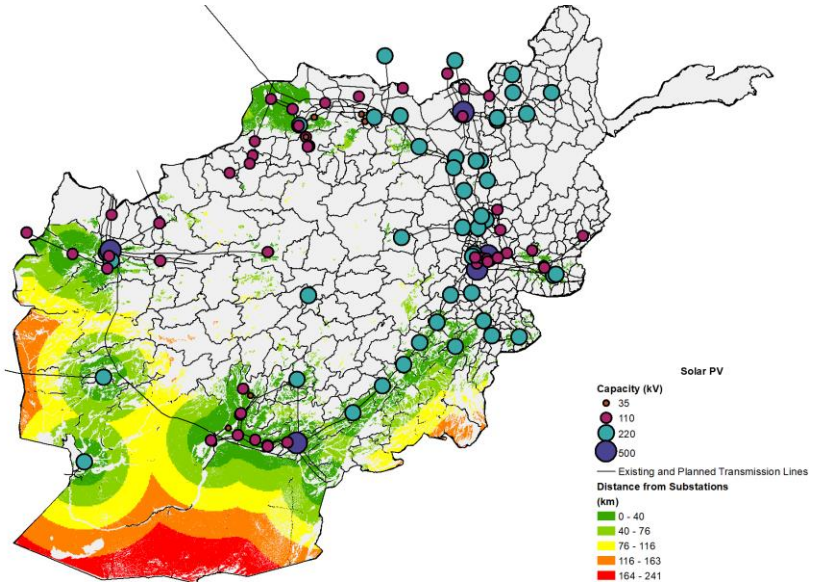
**Calculate attributes of each spatial unit**

Final stage - Several attributes are calculated for each spatial unit

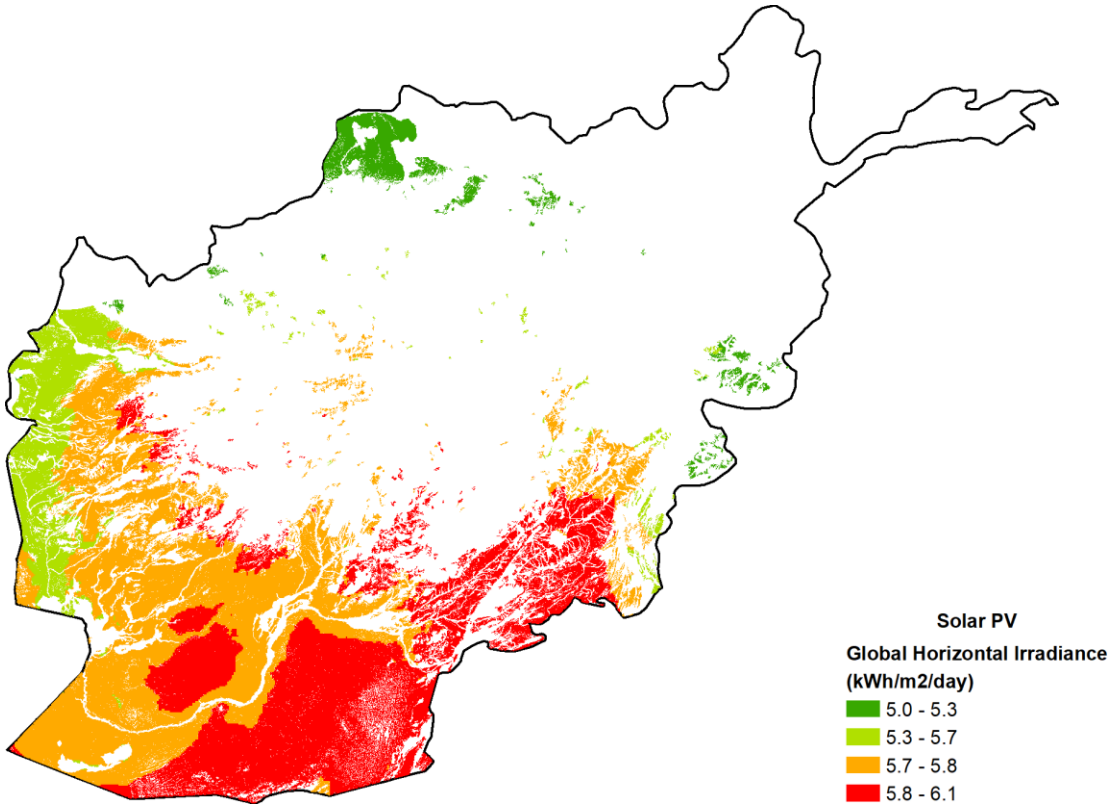
For example:

- Distance from closest transmission line
- Distance from closest substation
- Distance from closest road
- Distance from closest water body
- Mean slope
- Mean population density
- Mean global horizontal irradiance
- Mean wind power density
- Mean capacity factor
- Average annual electricity generation
- Average levelized cost of electricity



# Solar PV – Global Horizontal Irradiance




Long-term yearly average of daily totals of global horizontal irradiation (GHI) in kWh/m$^2$

Output from the global solar model SolarGIS derived from satellite digital images and atmospheric datasets

Period: from 1994/1999/2007 (depending on the region) to 2015

Spatial resolution: 30 arc-sec (900 m)

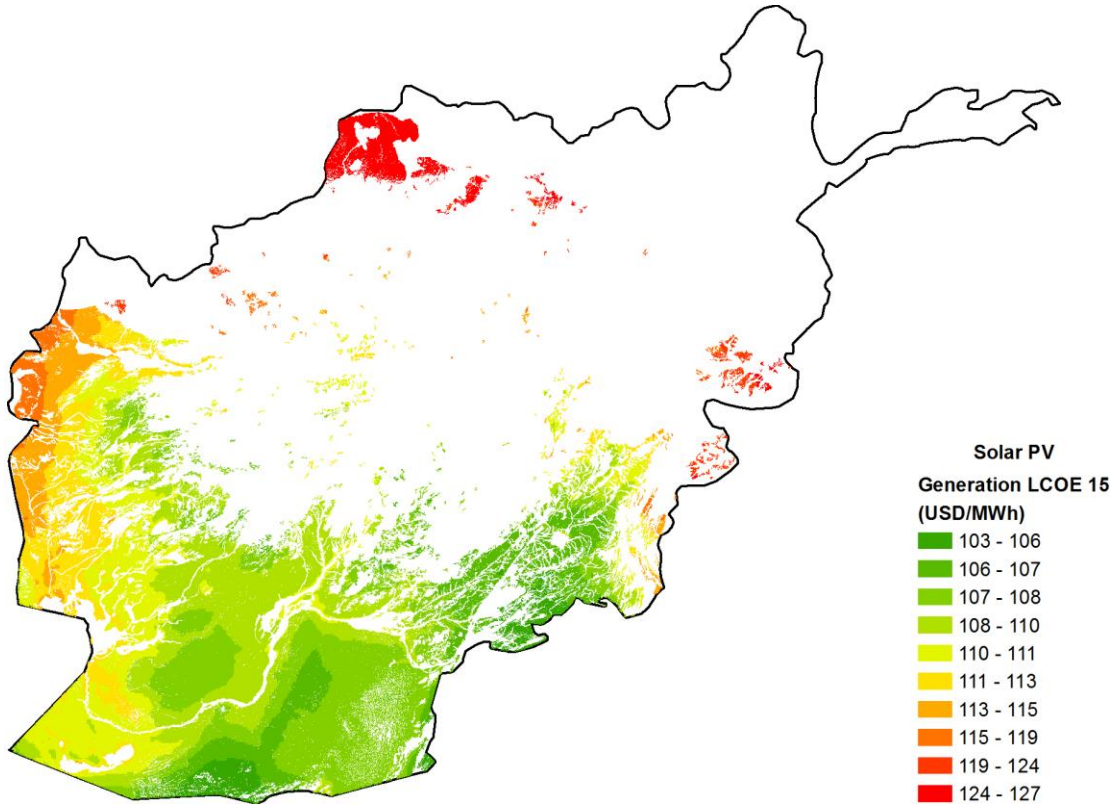
# Levelized Cost of Electricity (LCOE)

The LCOE (USD/MWh) describes the average cost of every unit of electricity generated over the lifetime of a project at the point of interconnection

The LCOE is calculated as the sum of 3 components:

- **Generation** LCOE;
- **Interconnection** LCOE; and
- **Road** LCOE

# Solar PV – Generation LCOE

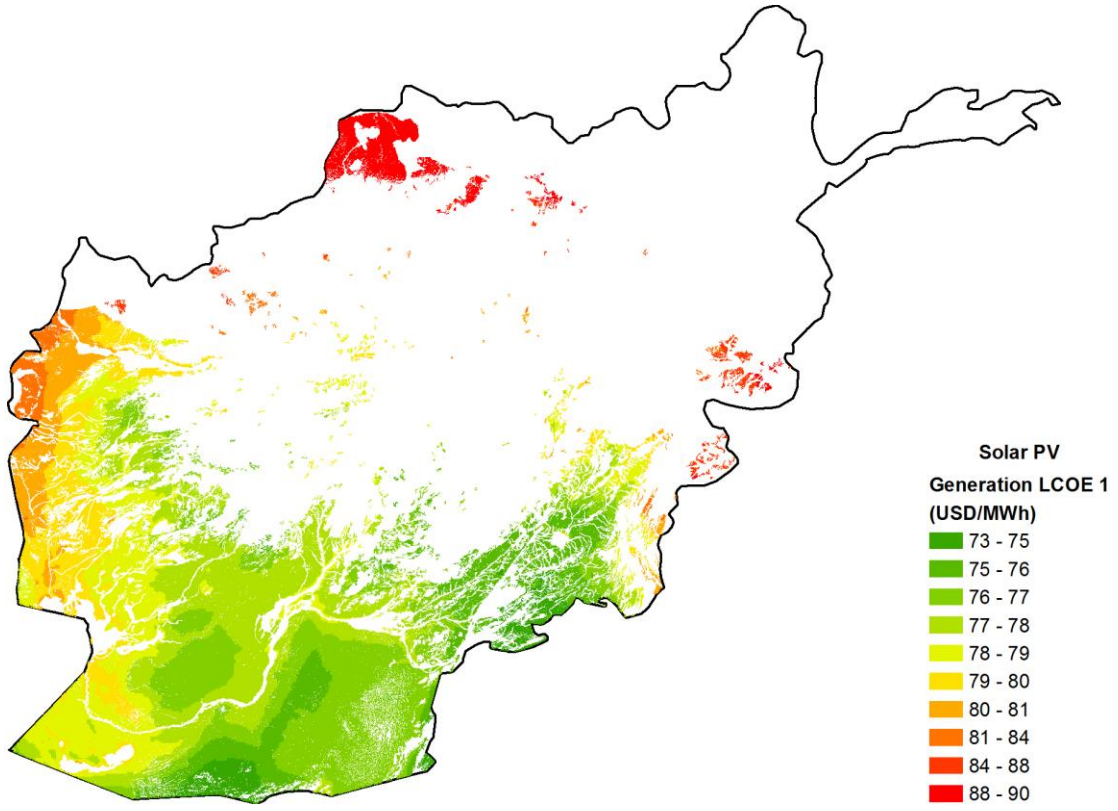



Average levelized cost of electricity (in USD/MWh) for the generation component.

Values estimated using the location, capacity factor and efficiencies specific to the technology

Capital costs = 1,500 [USD/kW]
Fixed O&M = 15,000 [USD/MW/y]
Variable O&M = 0

# Solar PV – Generation LCOE

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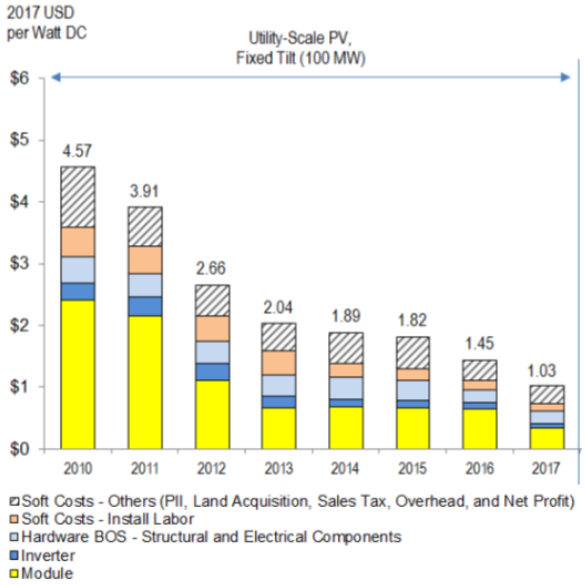
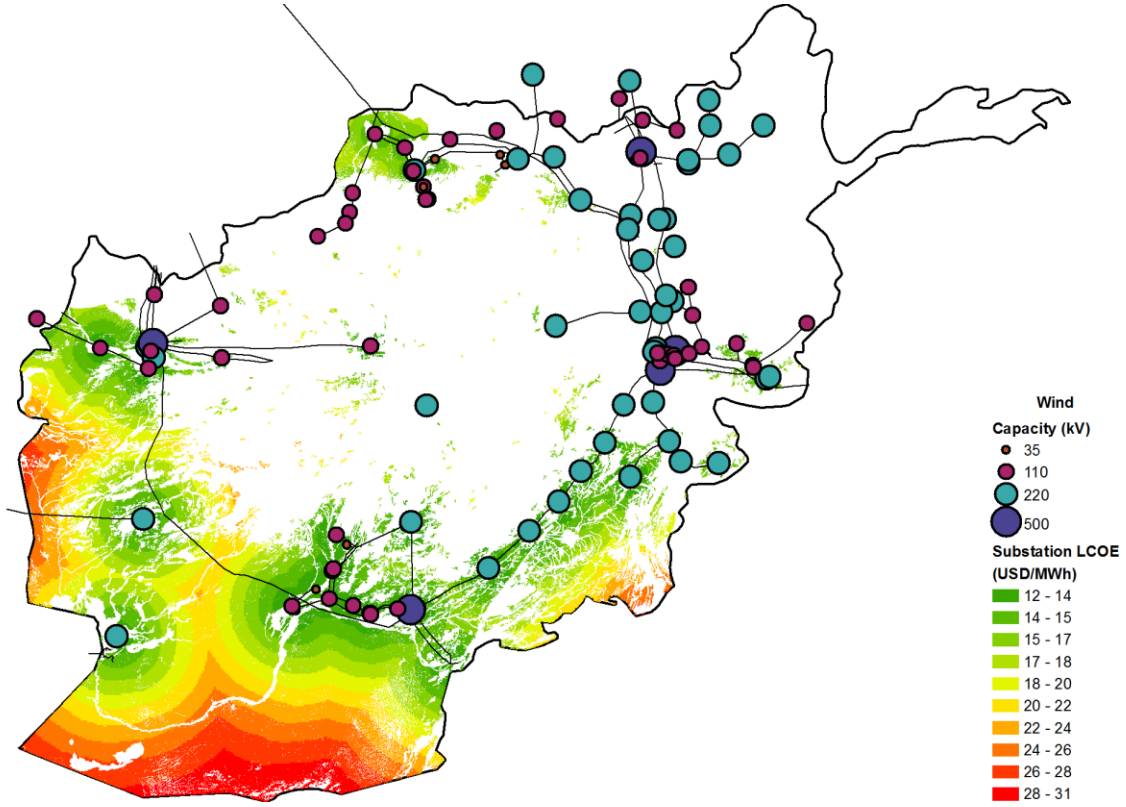



Capital costs = 1,030 [USD/kW]
Fixed O&M = 15,000 [USD/MW/y]
Variable O&M = 0

# Solar PV – Interconnection LCOE (to a substation)




Interconnection to nearest substation

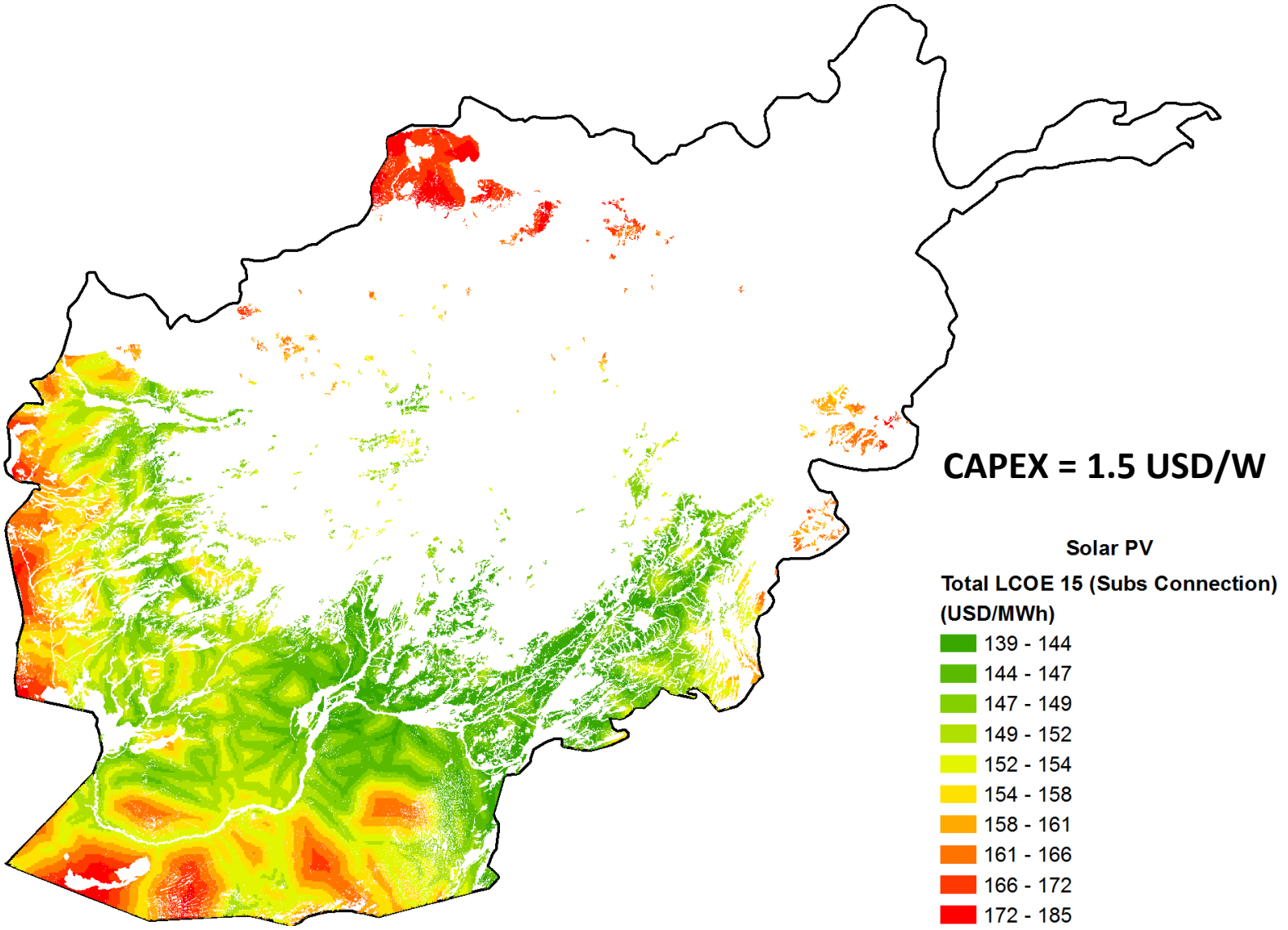
Interconnection cost depends on voltage, capacity and length of the line, type of conductor, structure of the poles, terrain, right-of-way, financing and material costs

Cost of transmission is assumed function of its length alone, holding all other cost parameters constant. Interconnection LCOE includes the cost of a substation

Transmission capital cost = 990 USD/MW/km;  Substation: 175,000 USD/MW

Negligible O&M costs

# Solar PV – Total LCOE



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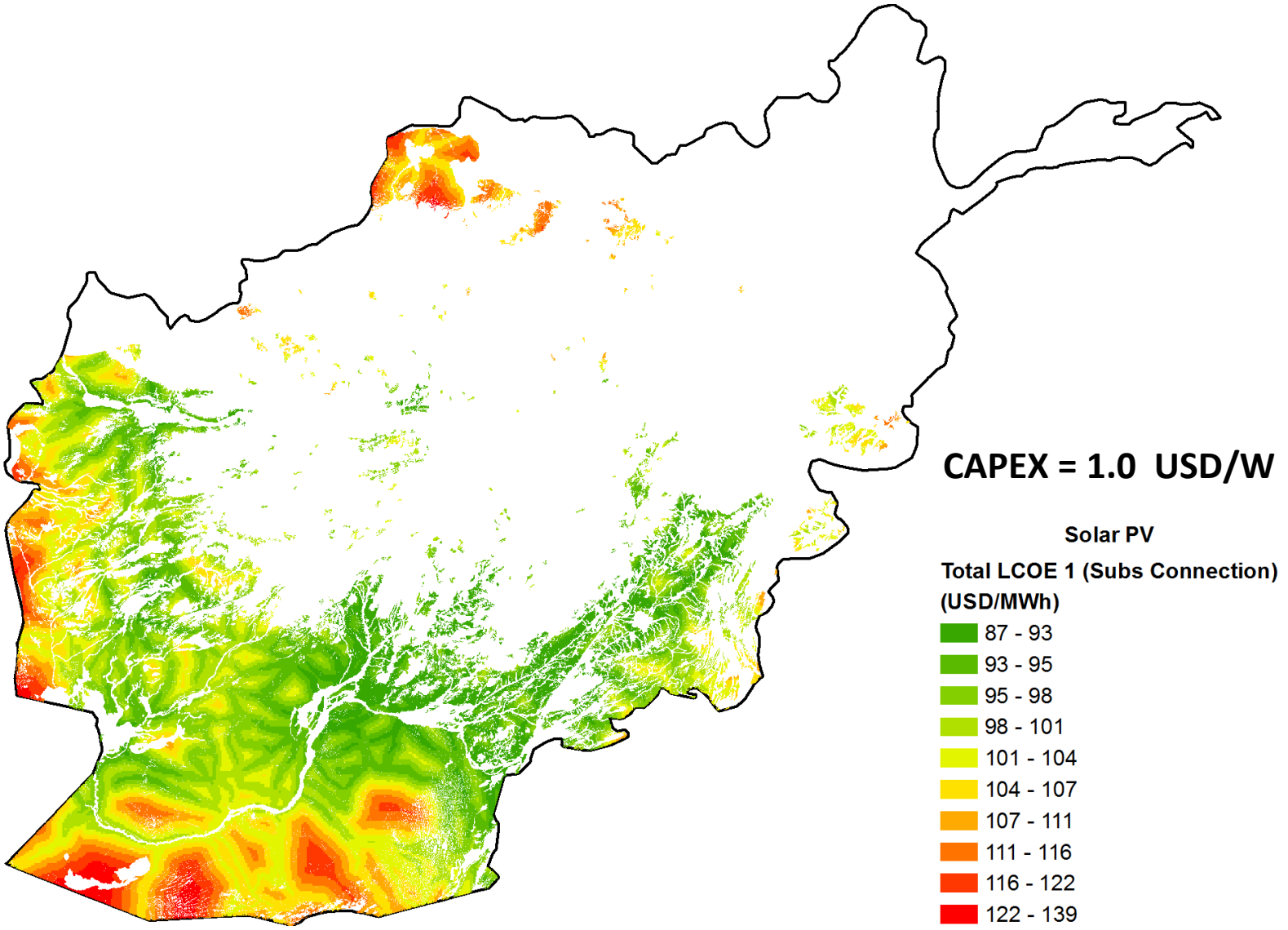
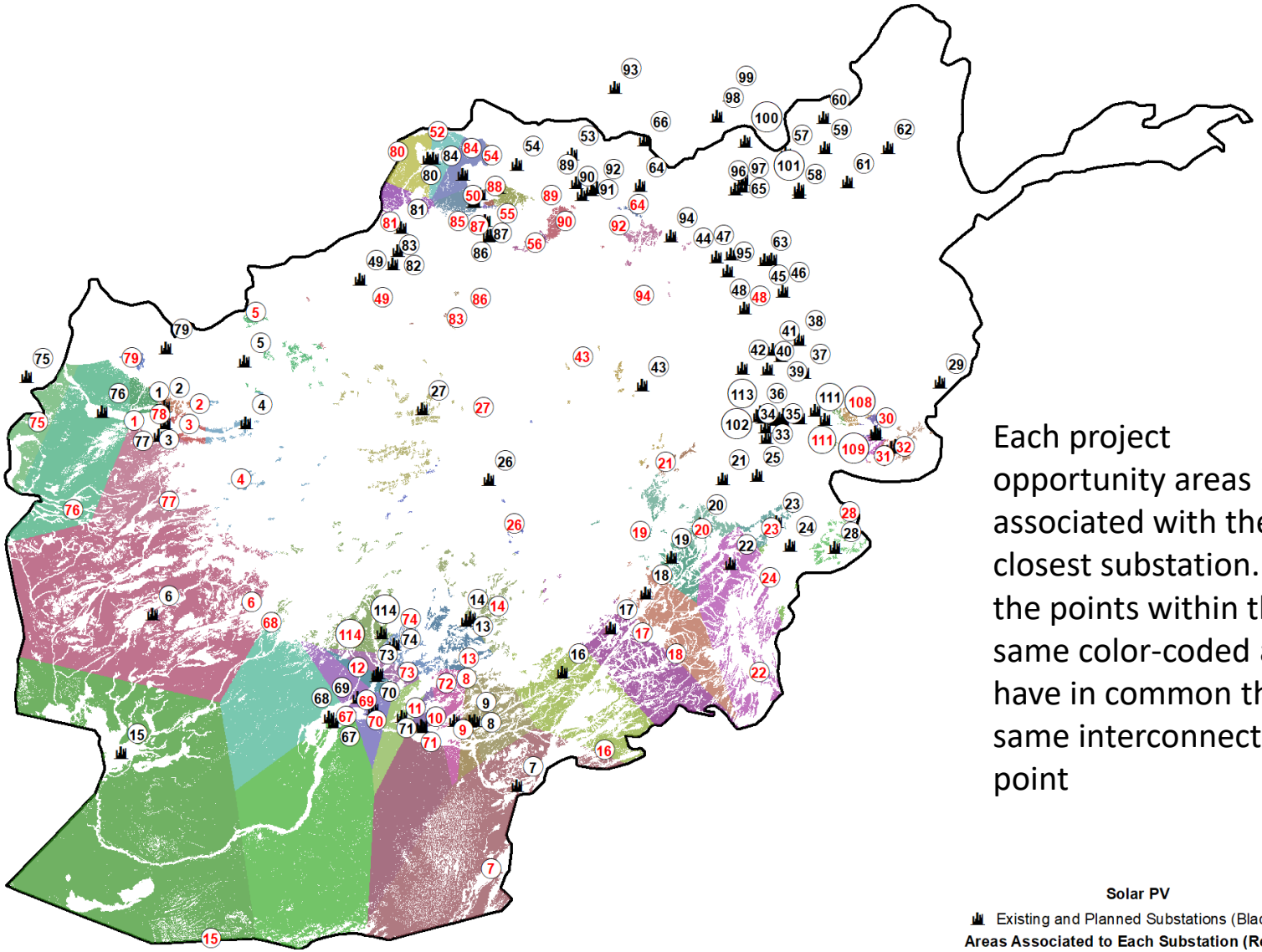


# Solar PV – Areas associated to each substation



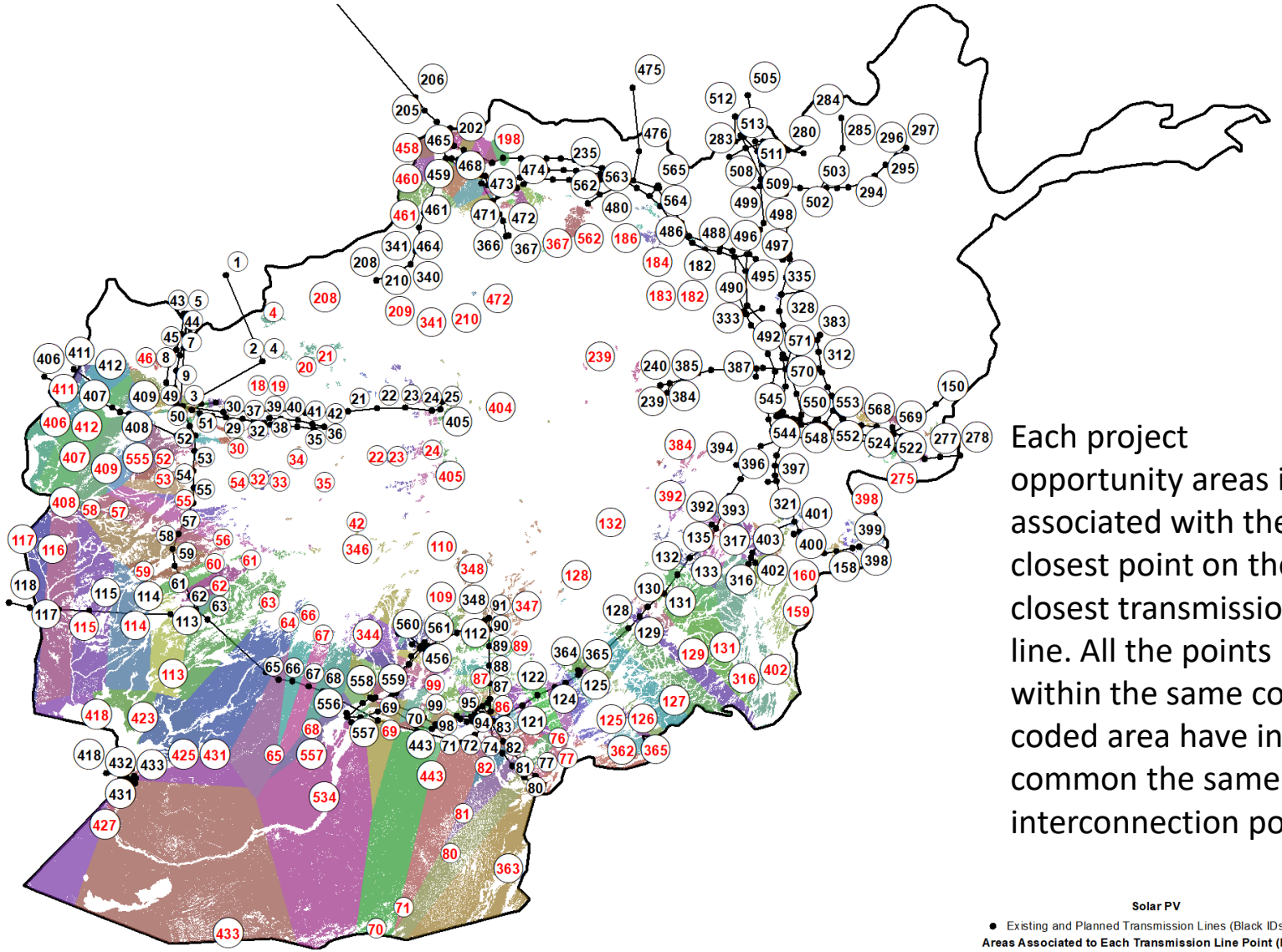
Each project opportunity areas is associated with the closest substation. All the points within the same color-coded area have in common the same interconnection point

**Solar PV**

Existing and Planned Substations (Black IDs)

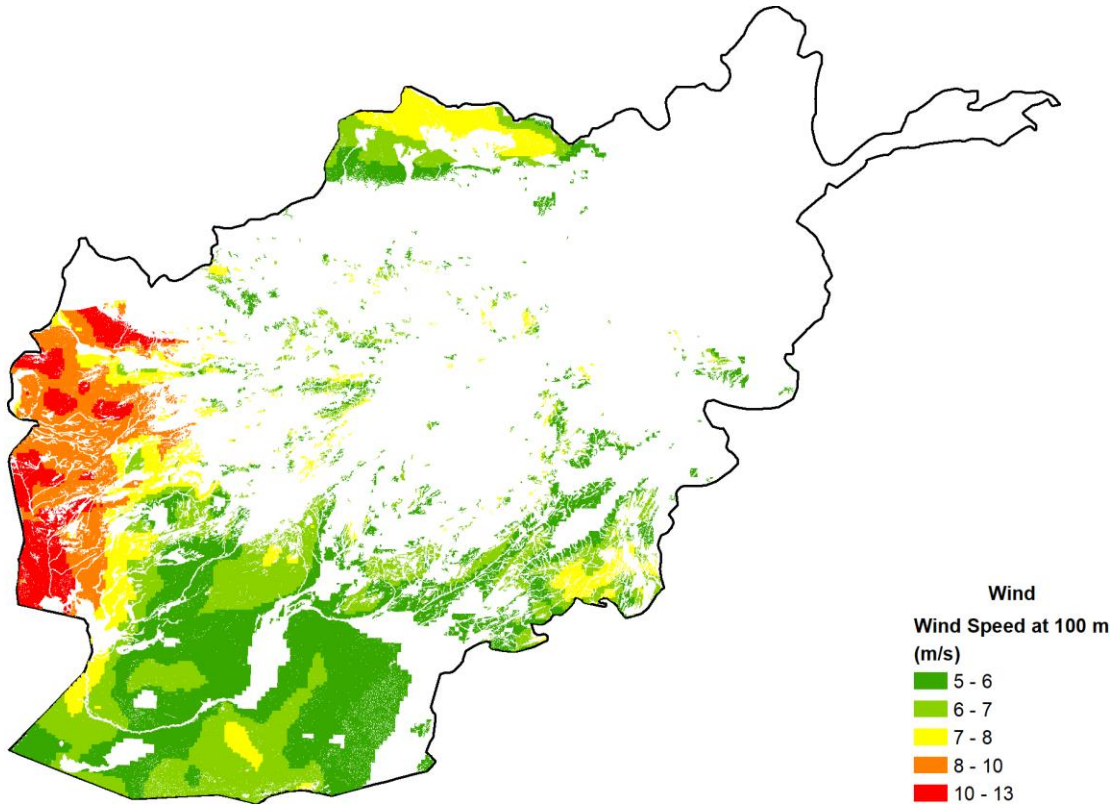
**Areas Associated to Each Substation (Red IDs)**

# Solar PV – Areas associated to each transmission line




Each project opportunity areas is associated with the closest point on the closest transmission line. All the points within the same color-coded area have in common the same interconnection point.

# Wind – Wind speed at 100 m



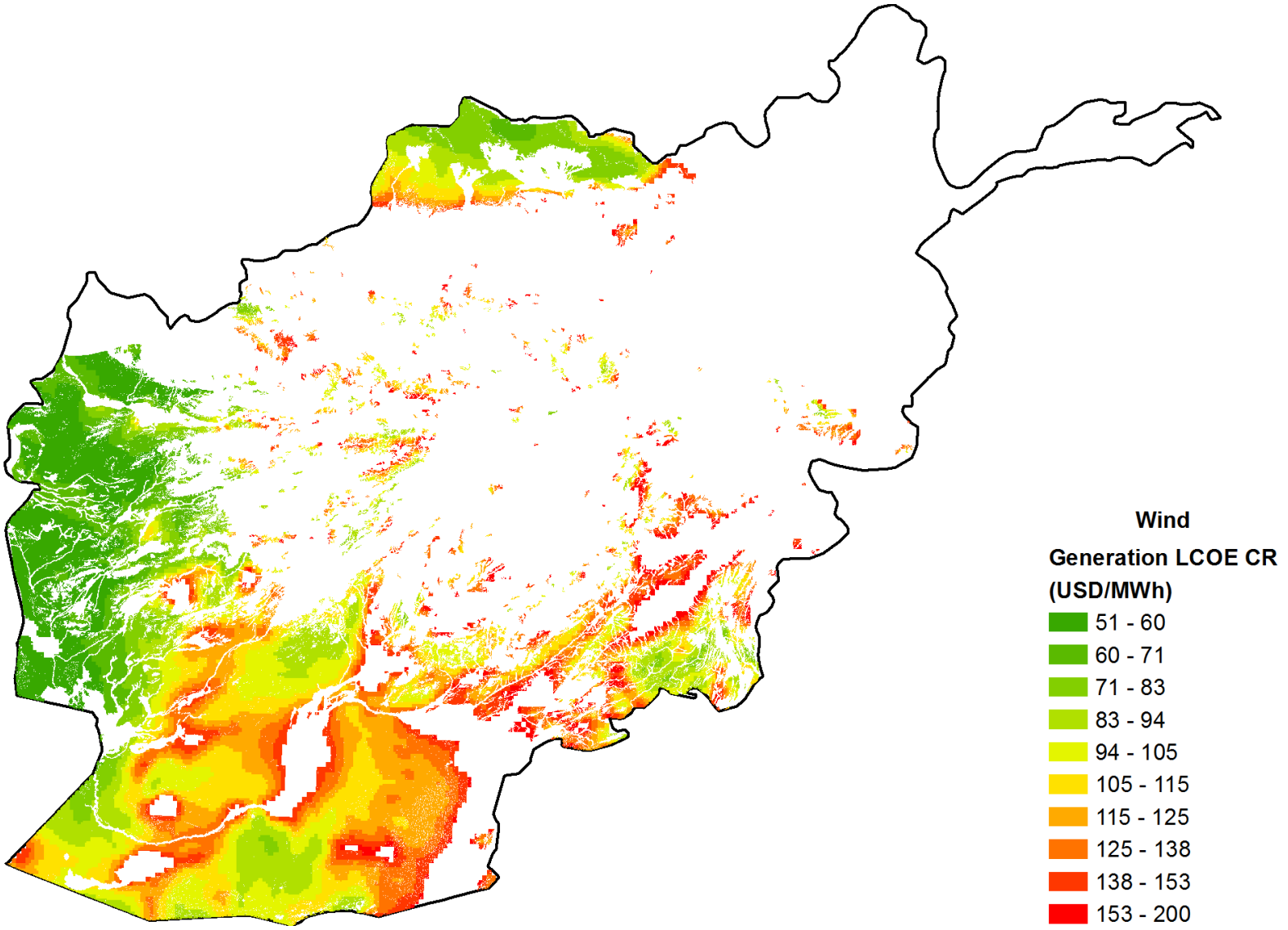

World Bank ESMAP Renewable Resource Mapping.

Mean wind speed field - Simulated

Period: Jan 2001 – Dec 2010 inclusive

Grid spacing: 0.05 degree (5 km)

# Wind – Generation LCOE

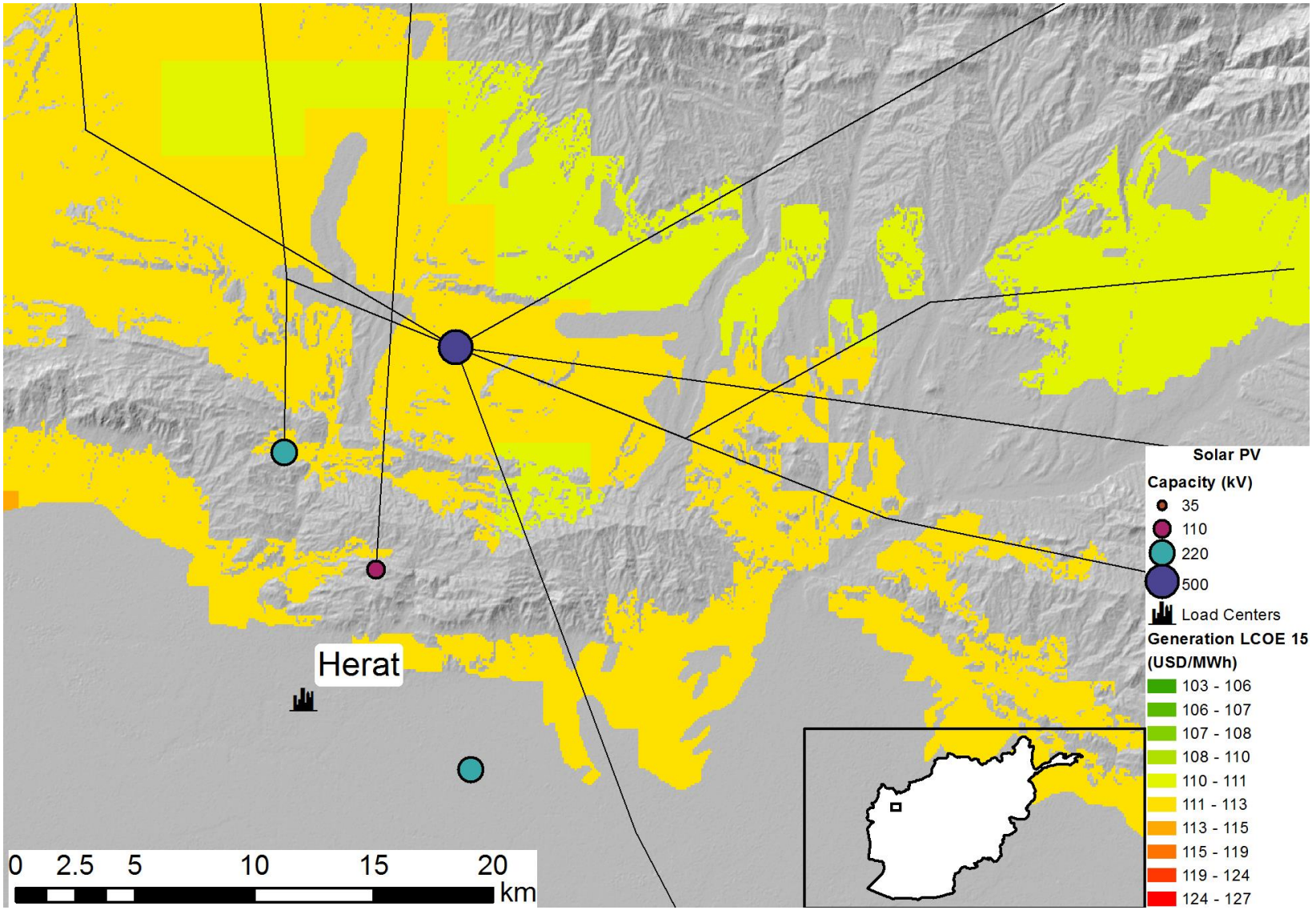


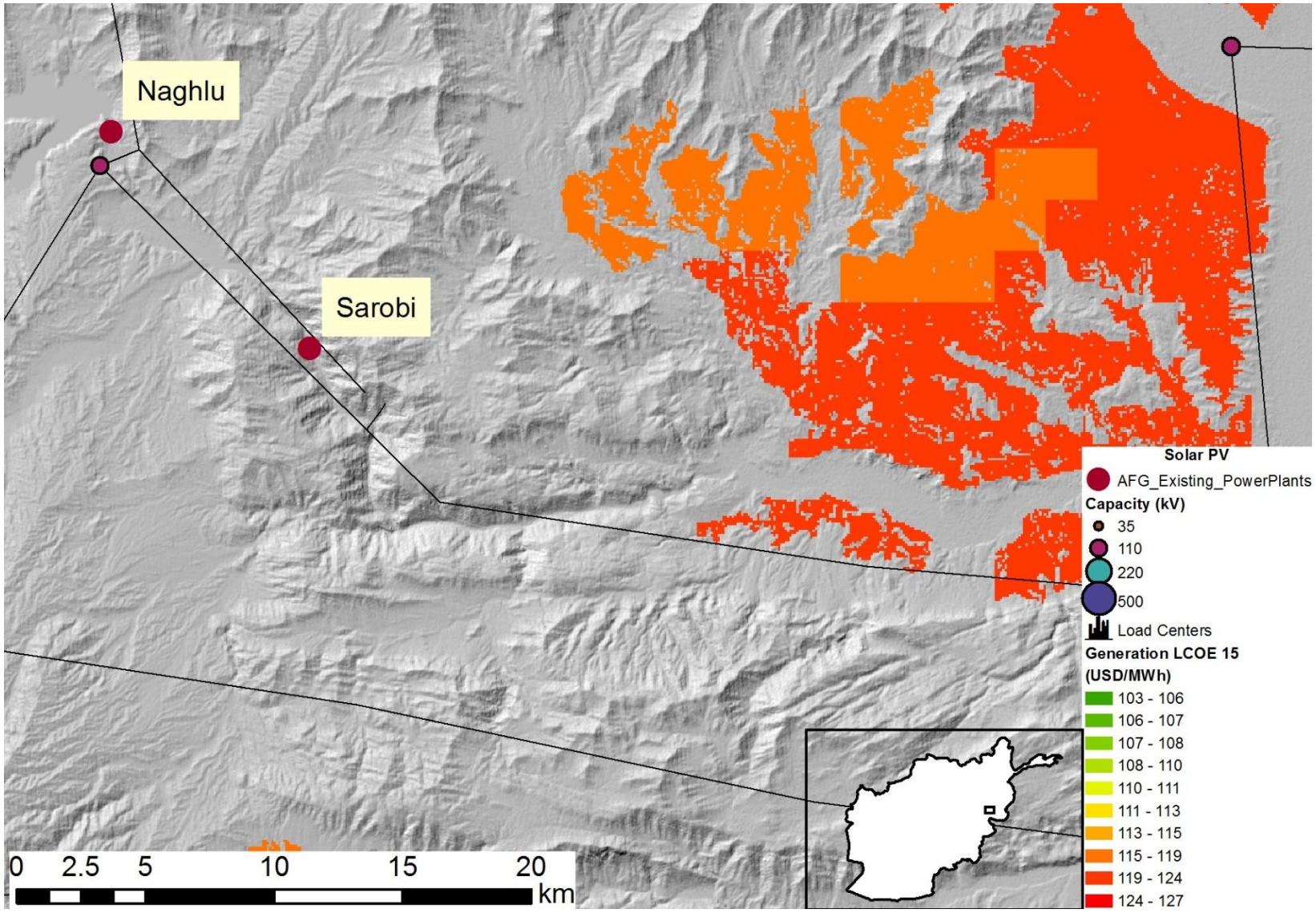
# Conclusions

- Geospatial analysis is a powerful and flexible tool for the identification and assessment of potential renewable energy development sites
- Initial large-scale assessment of entire potential development zones, subsequent investigation through targeted feasibility studies
- Attributes defined by the user according to their relevance
- Accuracy of the results can be improved by using updated and more reliable input information

# Next Steps and Data Gaps

- **More accurate data** on power system, economic and geopolitical factors
- **Shortlist of desired sites** and sizes
- **Simulate** how candidate sites work with Afghani power system – existing or planned, and identify the best sites.


Herat
0 2.5 5 10 15 20
km
Solar PV
Capacity (kV)
35
110
220
500
Load Centers
Generation LCOE 15
(USD/MWh)
103 - 106
106 - 107
107 - 108
108 - 110
110 - 111
111 - 113
113 - 115
115 - 119
119 - 124
124 - 127


Naghlu
Sarobi
Solar PV
AFG_Existing_PowerPlants
Capacity (kV)
35
110
220
500
Load Centers
Generation LCOE 15
(USD/MWh)
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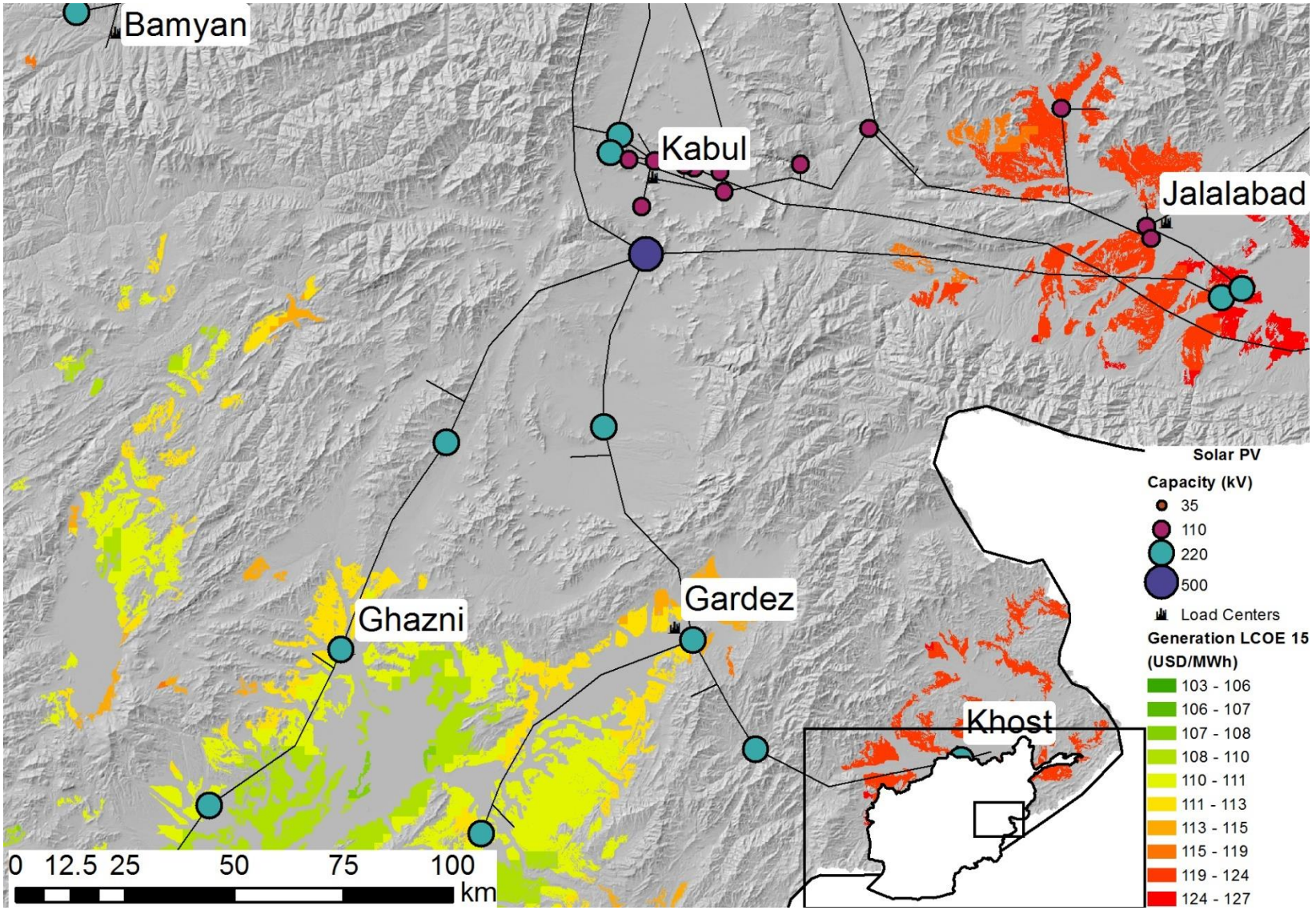
106 - 107
107 - 108
108 - 110
110 - 111
111 - 113
113 - 115
115 - 119
119 - 124
124 - 127
0 2.5 5 10 15 20
km


Bamyan
Kabul
Jalalabad
Ghazni
Gardez
Khost
Solar PV
Capacity (kV)
35
110
220
500
Load Centers
Generation LCOE 15
(USD/MWh)
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107 - 108
108 - 110
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111 - 113
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115 - 119
119 - 124
124 - 127
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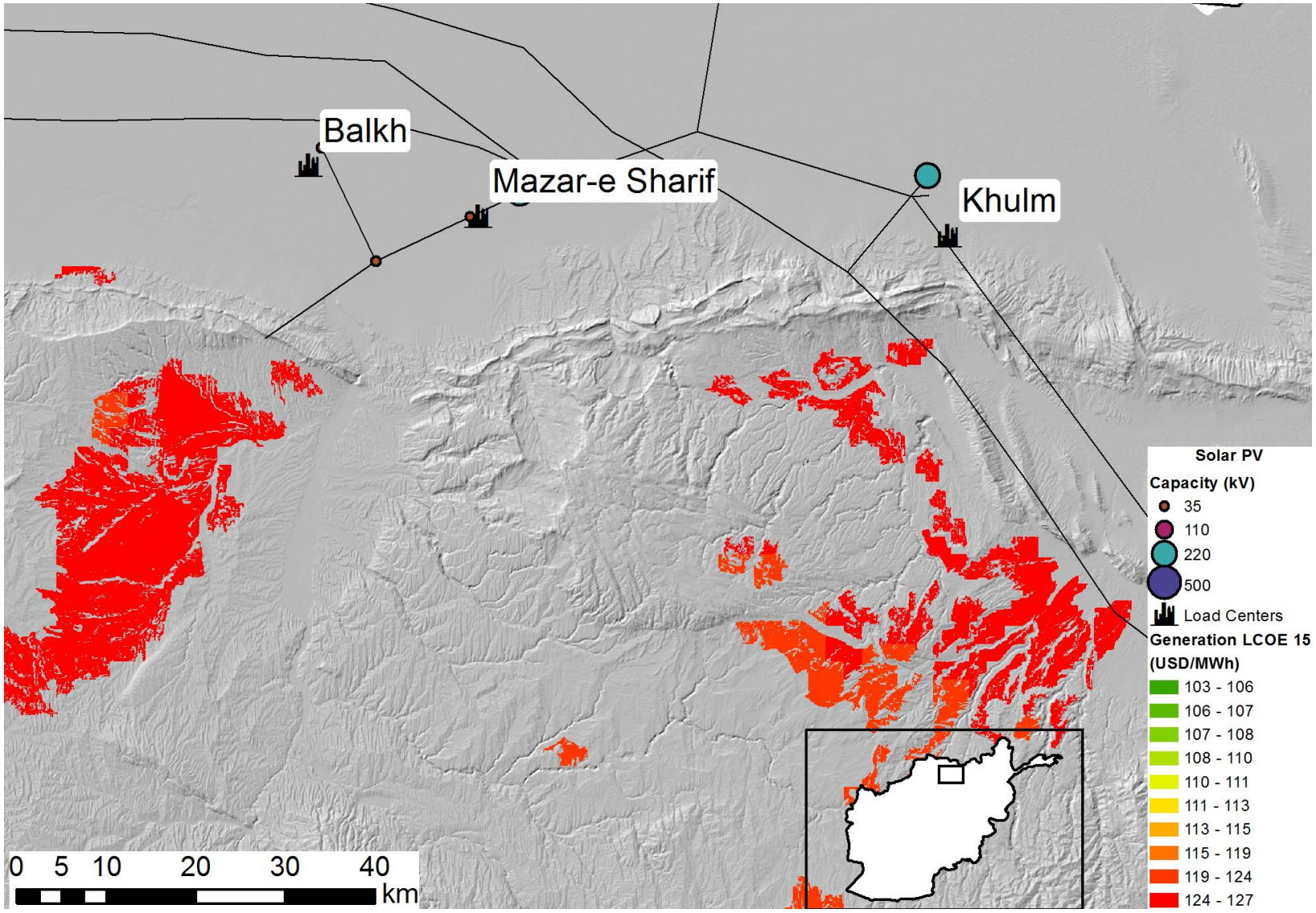
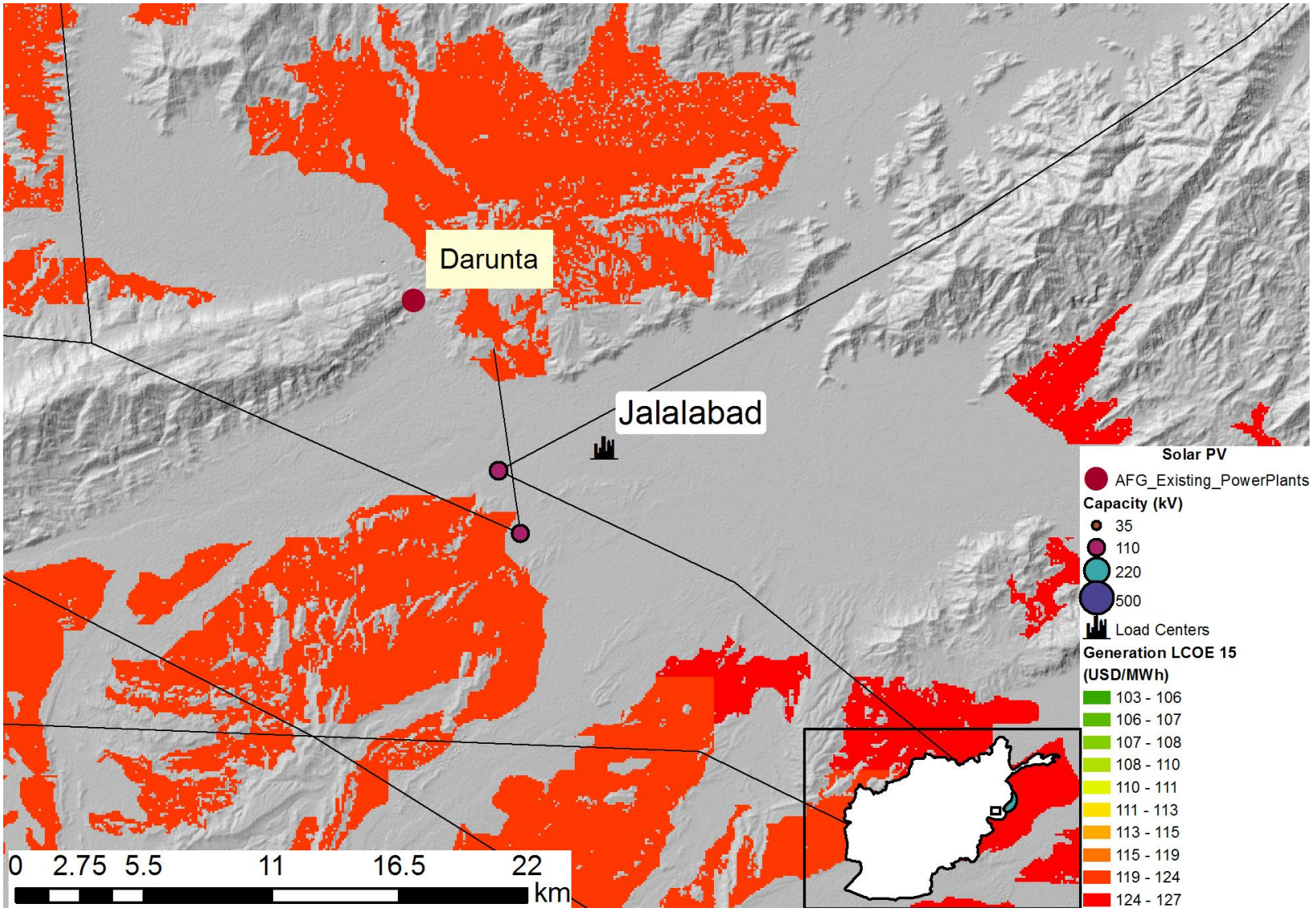
km


Balkh
Mazar-e Sharif
Khulm
Solar PV
Capacity (kV)
35
110
220
500
Load Centers
Generation LCOE 15
(USD/MWh)
103 - 106
106 - 107
107 - 108
108 - 110
110 - 111
111 - 113
113 - 115
115 - 119
119 - 124
124 - 127
0 5 10 20 30 40
km


Darunta
Jalalabad
Solar PV
AFG_Existing_PowerPlants
Capacity (kV)
35
110
220
500
Load Centers
Generation LCOE 15
(USD/MWh)
103 - 106
106 - 107
107 - 108
108 - 110
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111 - 113
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115 - 119
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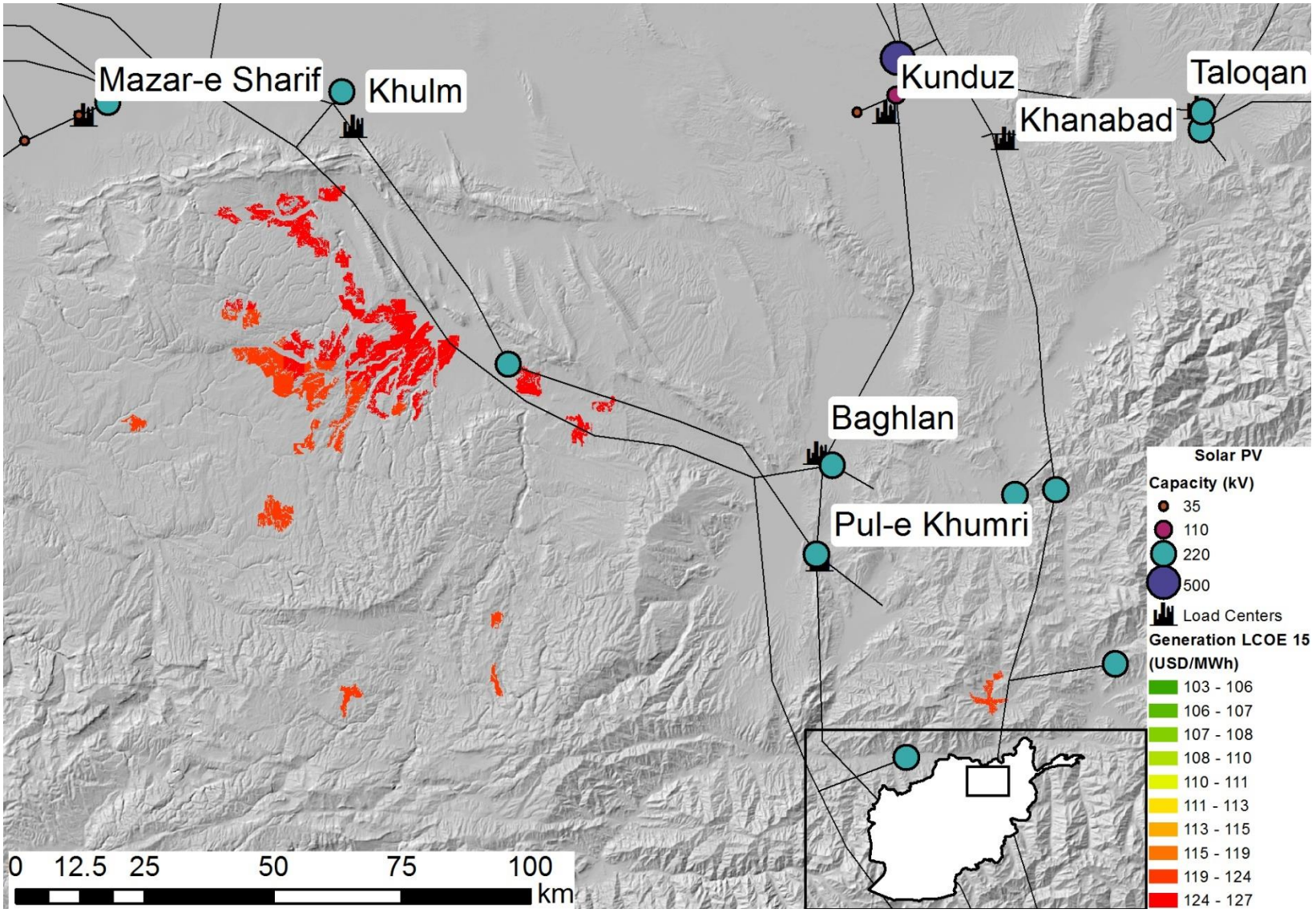
124 - 127
0 2.75 5.5 11 16.5 22
km


Mazar-e Sharif
Khulm
Kunduz
Taloqan
Khanabad
Baghlan
Pul-e Khumri
Solar PV
Capacity (kV)
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220
500
Load Centers
Generation LCOE 15
(USD/MWh)
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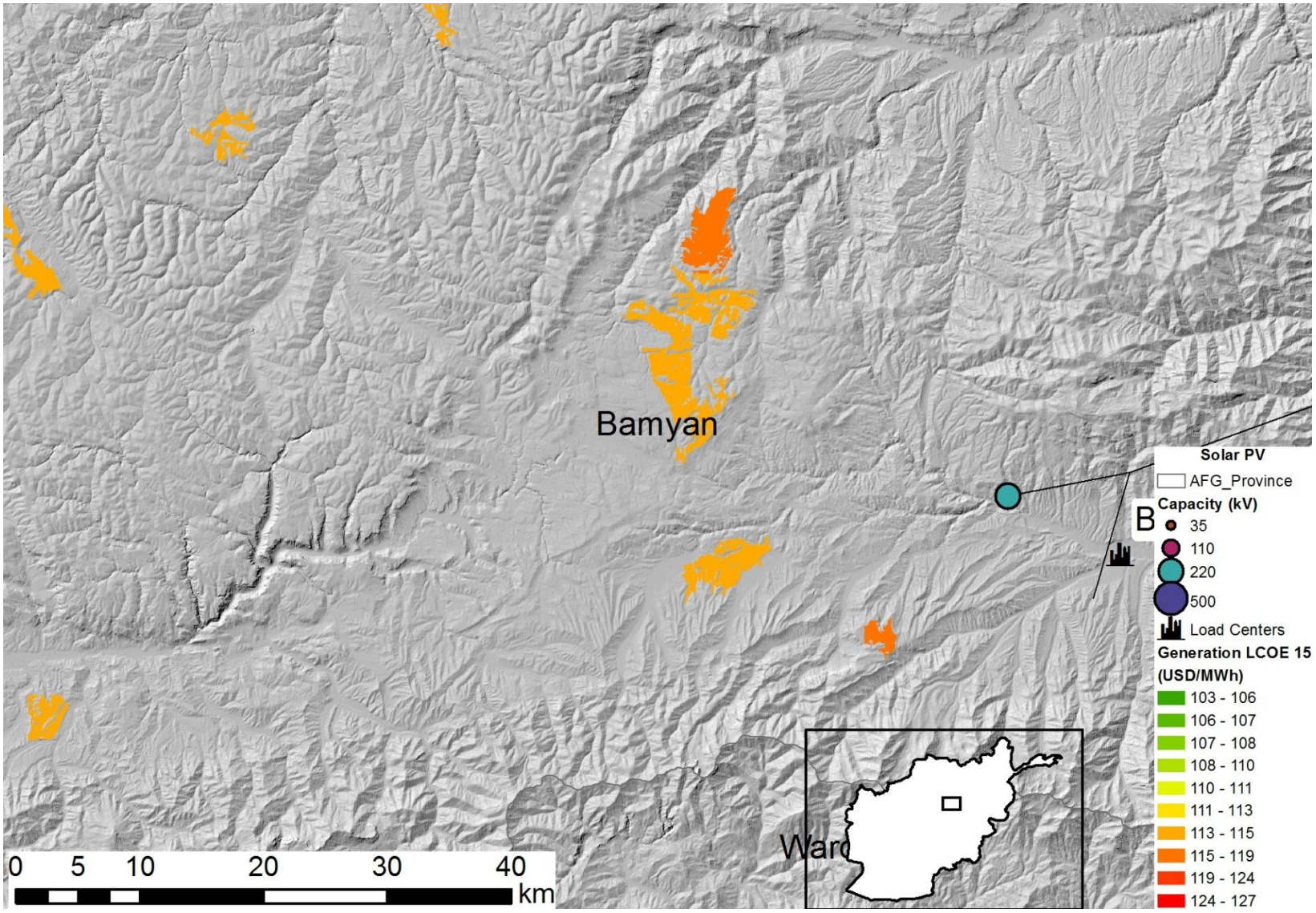
km


Bamyan
Solar PV
AFG_Province
Capacity (kV)
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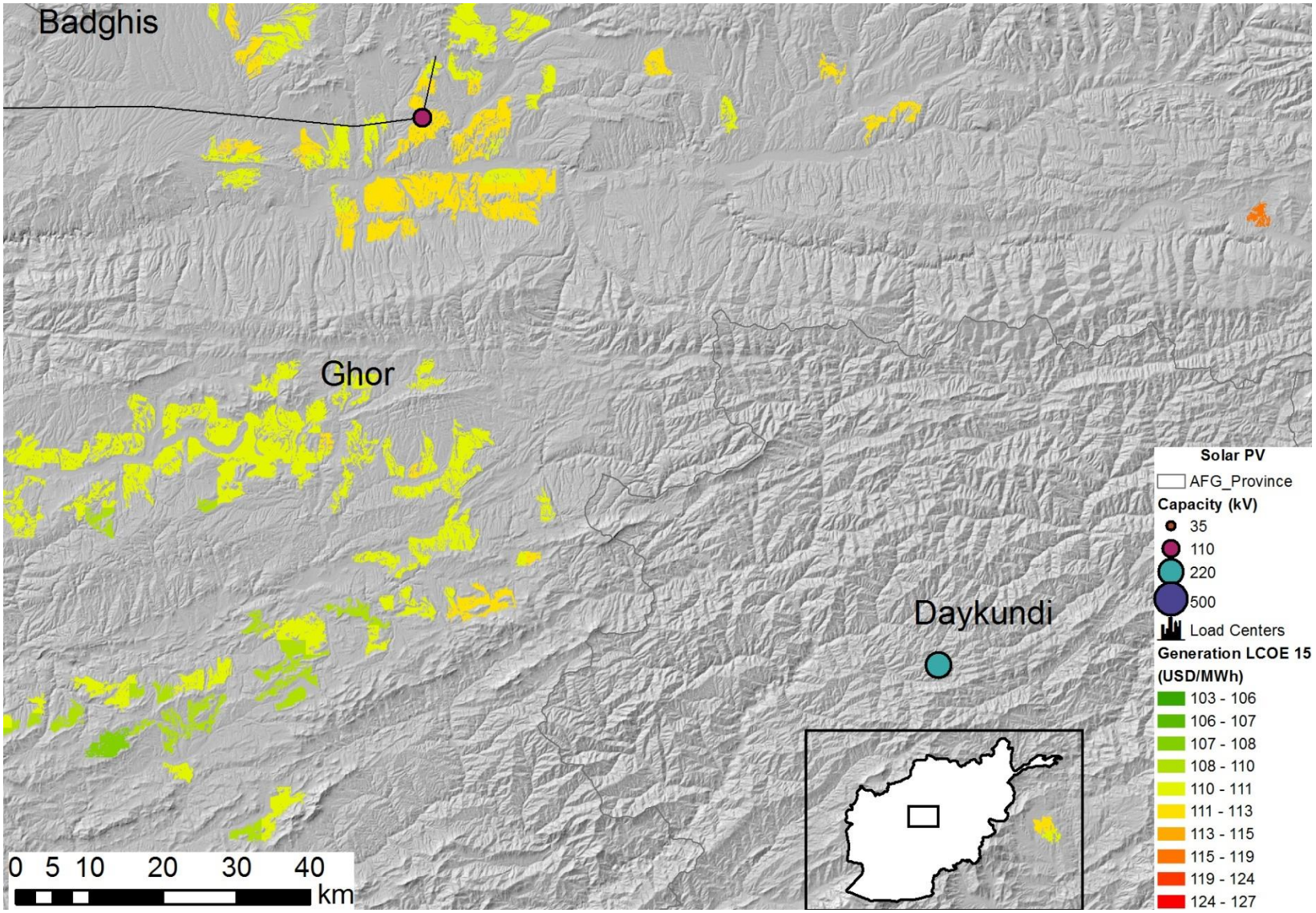
110
220
500
Load Centers
Generation LCOE 15
(USD/MWh)
103 - 106
106 - 107
107 - 108
108 - 110
110 - 111
111 - 113
113 - 115
115 - 119
119 - 124
124 - 127
0 5 10 20 30 40
km


Badghis
Ghor
Daykundi
0 5 10 20 30 40
km
Solar PV
AFG_Province
Capacity (kV)
35
110
220
500
Load Centers
Generation LCOE 15
(USD/MWh)
103 - 106
106 - 107
107 - 108
108 - 110
110 - 111
111 - 113
113 - 115
115 - 119
119 - 124
124 - 127

Thank you!

# Land and environmental assumptions

| Land Use Land Cover Class | Inclusion Criteria |
|---|---|
| Rangeland (grassland/forbs/low shrubs) | Included |
| Irrigated: Intermittently Cultivated | Excluded |
| Irrigated: Intensively Cultivated (1 Crop/Year) | Excluded |
| Rainfed Crops (sloping areas) | Excluded |
| Rock Outcrop / Bare Soil | Included |
| Marshland Permanently inundated | Excluded |
| Fruit Trees | Excluded |
| Rainfed Crops (flat lying areas) | Excluded |
| Settlements | Excluded |
| Natural Forest (closed cover) | Excluded |
| Natural Forest (open cover) | Excluded |
| Irrigated: Intensively Cultivated (2 Crops/year) | Excluded |
| Degenerate Forest/High Shrubs | Excluded |
| Water Bodies | Excluded |
| Permanent Snow | Included |
| Marshland Seasonal | Excluded |
| Vineyards | Excluded |
| Sand Covered Areas | Included |
| Sand Dunes | Included |
| Pistachio Forest | Excluded |
| Gardens | Excluded |

# Cost assumptions

**Need updated cost assumptions specific to Afghanistan**

| Parameter | Solar PV | Wind | Notes |
|---|---|---|---|
| Capital cost (USD/MW) | 1,500,000<br>1,030,000 | 1,700,000 | Capital cost of the generation technology per MW of capacity. The capital cost for wind technology assumes Class III turbines |
| Variable O&M cost of generation (USD/MWh) | 0 | 0 | Variable operations and maintenance cost of generation |
| Fixed O&M cost of generation (USD/MWh) | 15,000 | 20,000 | Fixed operations and maintenance cost of generation in units of USD per MWh. |
| Transmission cost (USD/MW/km) | 990 | 990 | Capital cost for a transmission line in units of USD per MW per km |
| Substation cost (USD/MW) | 175,000 | 175,000 | Cost of a substation. This cost is added to any new interconnections to represent the average cost of construction of a new substation |
| Road cost (USD/km) | 407,000 | 407,000 | Capital cost for the construction of a new road |
| Economic discount rate (%) | 12.5% | 12.5% | Cost of capital or interest rate used to determine the present value of future cash flows. This discount rate is used to estimate the levelized cost of electricity. |

# Additional Attributes of Each Potential Site

**Need identification of additional relevant area attributes in Afghanistan**

| |
|---|
| Distance from closest transmission line |
| Identity of closest transmission line point |
| Distance from closest substation |
| Identity of closest substation |
| Distance from closest road |
| Distance from closest planned solar PV project |
| Distance from closest load center |
| Distance from closest water body |
| Mean elevation |
| Mean slope |
| Mean population density |
| Mean global horizontal irradiance |
| Mean wind power density |
| Mean wind speed |
| Mean capacity factor |
| Average annual electricity generation |
| Average levelized cost of electricity (in USD/MWh) for interconnection to transmission line component |
| Average levelized cost of electricity (in USD/MWh) for interconnection to substation component |
| Average levelized cost of electricity (in USD/MWh) for road construction component |
| Average levelized cost of electricity (in USD/MWh) for generation component |
| Average total levelized cost of electricity (in USD/MWh) if interconnected to transmission line |
| Average total levelized cost of electricity (in USD/MWh) if interconnected to substation |