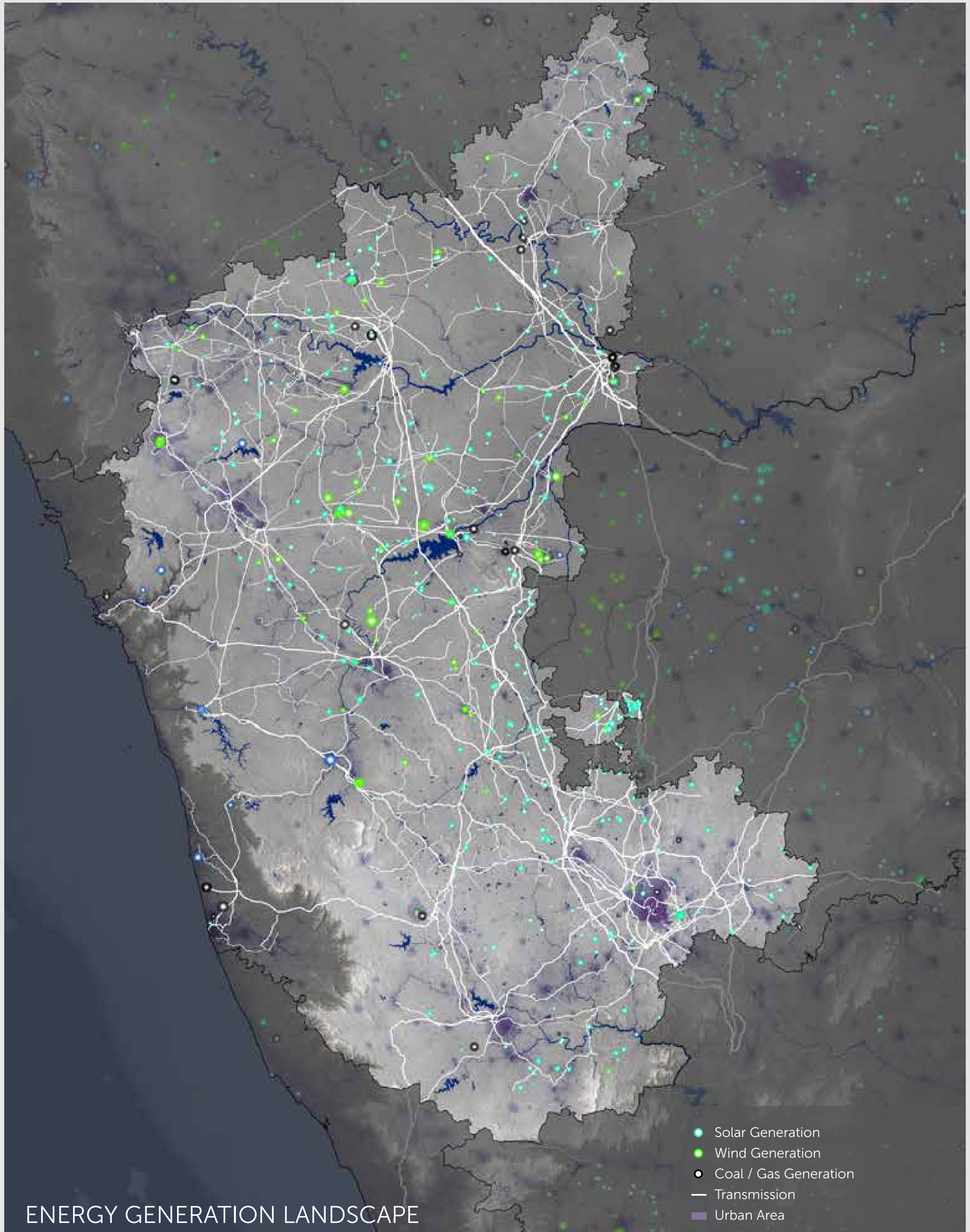


INTEGRATING THE ENERGY LANDSCAPE MOSAIC
KARNATAKA STATE

- Karnataka's energy transition will require major solar expansion.
- Solar expansion raises important questions of land-use compatibility among competing priorities.
- Rural livelihoods often overlooked when siting utility-scale solar.
- Spatial planning can help direct solar toward lower-conflict landscape configuration.

LAND USE PRIORITIES

Solar Suitability | Environmental Integrity | Agricultural Production

SOCIO-ECONOMIC CONSIDERATIONS

Agrarian Livelihood Sensitivity | Social Vulnerability

ANALYTIC FRAMEWORK

TIME SERIES

Current

Projected - 2050

→

ENERGY EVALUATION

Generation Capacity (MW)

Land Use Intensity (MW/sq Km)

Total Land Use Demand (sq Km)

↓

LAND CONVERSION

Naturalized Vegetation

Agriculture

ANALYTIC FRAMEWORK

LAND-USE

Solar Priority (50%)
- Distance from Transmission Infrastructure (40%)
- Solar Radiation Exposure (30%)
- Terrain Slope (30%)

Env. Protection Priority

Avoid
- Forested Area

Prioritize
- Sparse Vegetation
- High aridity

Exclude
- Senstive and Protected Areas
- Urban Areas

Agricultural Priority

Avoid
- Surface Irrigated
- Groundwater Irrigated

Prioritize
- Rainfed agriculture
- Areas with high groundwater extraction

SOCIO-ECONOMIC

Social Vulnerability (50%)
- Scheduled Caste + Tribe (20%)
- Literacy Rate (20%)
- Households w/o electricity (20%)
- Households w/o sanitation (20%)
- Households w/o assetsts (20%)

Livelihood Sensitivity (50%)
- Cultivators and Agricultural laborers (30%)
- Agricultural laborers (40%)
- Marginal workers (30%)

Land-Use Suitability (50%)

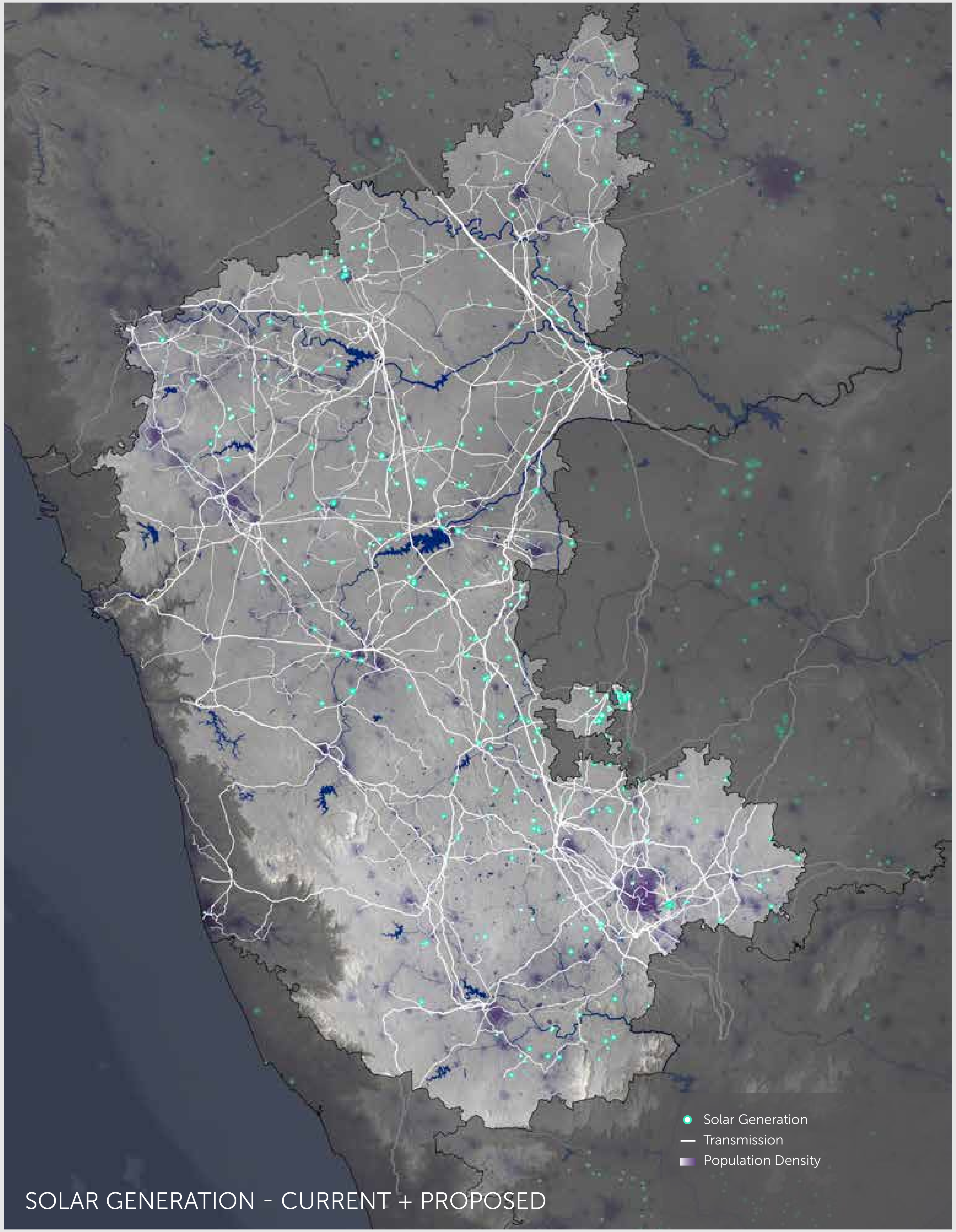
Socio-Economic Vulnerability (50%)

Solar Siting Suitability (50%)

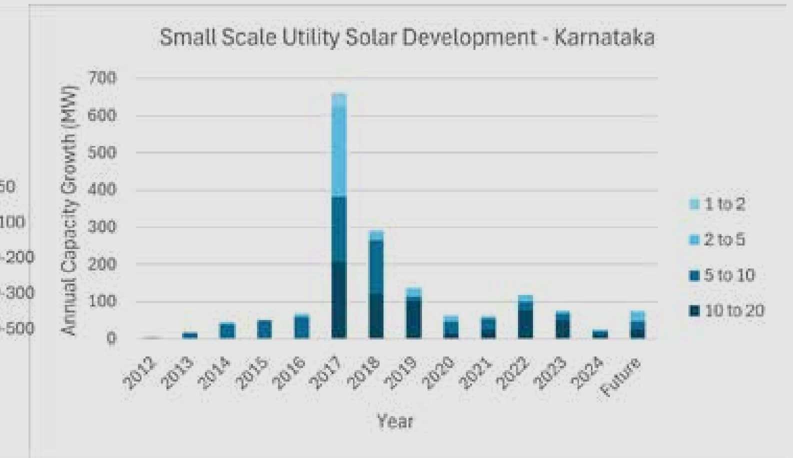
ENERGY LANDSCAPE MOSAIC
INTEGRATED SOLAR DEVELOPMENT SUITABILITY

SCORING FRAMEWORK

Block Tier II	Block Tier I	Criterion	Tier	Normalized Score (0 to 100)	Rationale
Solar Siting Suitability (50%)	Solar Priority (50%)	Distance to Transmission (50%)	0 to 2 km	100	Majority of existing solar development is within 2km of Transmission Infrastructure
			2 to 5 km	75	
			5 to 10 km	50	
			10 to 15	25	
			>20km	0	
		Solar Resource - PVOut (20%)		Normalized 0 to 100	Weighted lower since current development seems relatively agnostic, and Karnataka is fairly clustered and uniform in comparison to the breadth of nation-wide development
		Slope (30%)	0 to 3 deg	100	Rough Interpretation of typical solar development constraints
			3 to 5 deg	75	
			5 to 10 deg	50	
			10 to 15 deg	25	
			> 15 deg	0	
	Land Use Suitability (50%)	Environmental Protection Priority	Protected Areas	Exclude	Excluded as highest independently verified Environmental Protection Priority
			Sensitive Wildlife Areas	Exclude	
			Urban land use	Exclude	Exclusion is necessary as urban areas rank comparatively lower in livelihood senssitivity
			Sparse Vegetation	100	Preferred land use given exisitng arbitrage priority.
			Forest	0	Not excluded but ranked lowest as a sensitive and threatened ecosytem.
			Water/Wetland	0	Sensitive and Impractical for Development
		Agricultural Production Priority	Canal Irrigated	0	Coincides with best agricultural resources and reliable irrigation infrastructure
			Groundwater Irrigated and Over-Exploited	75	High Agricultural resource suitability, but over-exploited groundwater makes it suitable for conversion as an opportunity to relieve groundwater over-extraction
			Groundwater Irrigated and Critical	50	
			Groundwater Irrigated and Semi-Critical	25	
			Groundwater Irrigated and Safe	15	
			Rainfed Agriculture	75	Lack of intensive irrigation infrastructure interpreted as a lack of ag resource suitability and low productivity
Socio-Economic (50%)	Livelihood Sensitivity (50%)	Ag workers share (30%)		Normalized 0 to 100	Total share of population implicated in agricultural economy
		Ag labourers share (40%)		Normalized 0 to 100	Landless workers reliant on agricultural economy. Would be acutely vulnerable in a land conversion scenario, and unlikely to gain from land leases.
		marginal workers share (30%)		Normalized 0 to 100	Landless workers with inconsistent livelihood. Likely to be vulnerable to land conversion.
	Social Vulnerability (50%)	SC/ST Share (20%)		Normalized 0 to 100	All notable and diverse indicators of social vulnerability, which would also indicate vulnerability to livelihood and land-use changes. Weighted equally.
		Illiteracy Rate (20%		Normalized 0 to 100	
		No electricity rate (20%)		Normalized 0 to 100	
		No latrine share (20%)		Normalized 0 to 100	
		No assets share (20%)		Normalized 0 to 100	
Indicators to include in future Model Iterations		Income Poverty Indicators			Further refine and compliment current socio-economic indicators
		Proxies for Land Valuation			High land prices may make solar development impractical.



CURRENT SOLAR CAPACITY

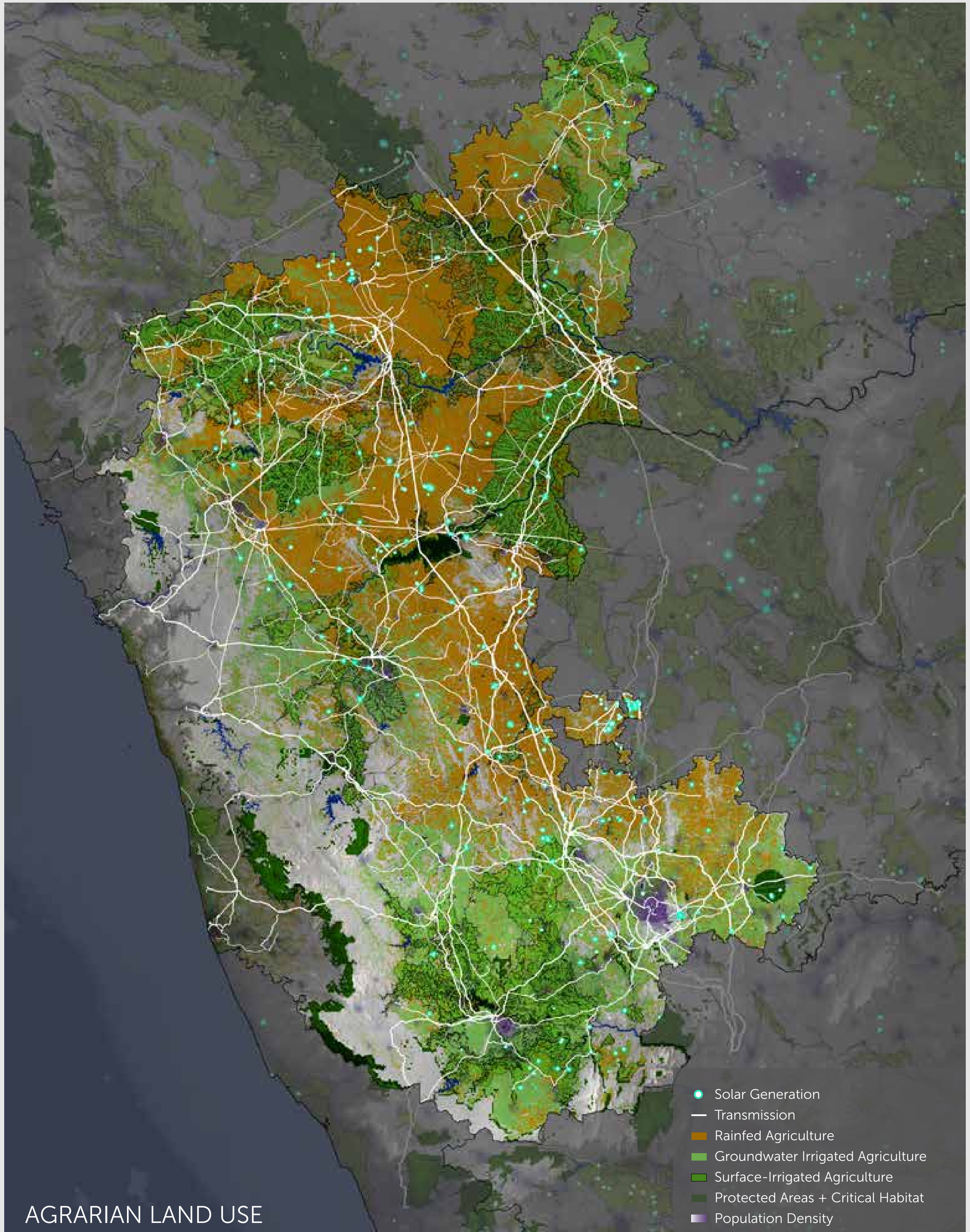


Energy Mix - Karnataka					
	2023		2032 - Projected 3.93% CAGR		
Source	Contracted Capacity (MW)	Percentage	Contracted Capacity (MW)	Percentage	Growth
Coal	9,610	32.3%	14,750	34.4%	153%
Nuclear	697	2.3%	689	1.6%	99%
Hydro	4,687	15.8%	4,823	11.2%	103%
Solar	7,627	25.6%	10,993	25.6%	144%
Wind	5,250	17.7%	9,453	22.0%	180%
Bioenergy	1,870	6.3%	2,201	5.1%	118%
Total	29,738		42,909		144%
Annual Generation (TWh)	98.9		142.7		144%

CURRENT LAND USE DEMAND

Land Use Demand for Solar Development			
Solar Project Size (MW)	Land Use Factor (ha/MW)		
	Low	Mid	High
1–20	2	2.8	3.5
20–100	2	2.6	3.2
100–500	1.8	2.4	3

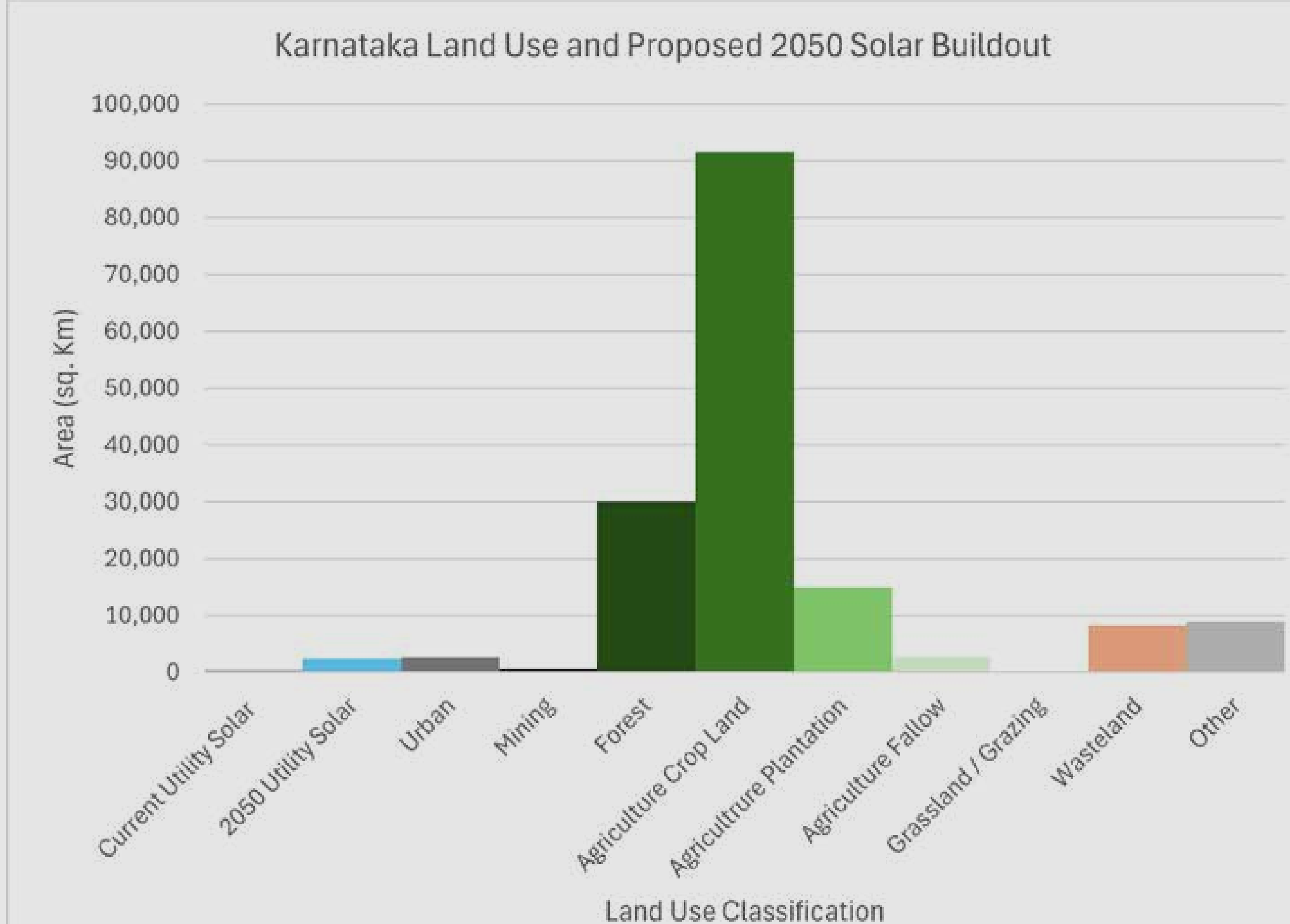
2025 Solar Capacity and Land Use Demand (Utility Scale)					
Status	Solar Project Size (MW)	Solar Capacity (MW)	Land Use Estimate (ha)		
			Low	Mid	High
Operating	1–20	1,686	3372.6	4,722	5,902
	20–100	4,255	8509.6	11,062	13,615
	100–500	2,945	5301	7,068	8,835
	Total	**8,886**	**17,183**	**22,852**	**28,352**
Proposed	1–20	0	0	0	0
	20–100	504	1008	1,310	1,613
	100–500	2,070	3726	4,968	6,210
	Total	**2,574**	**4,734**	**6,278**	**7,823**

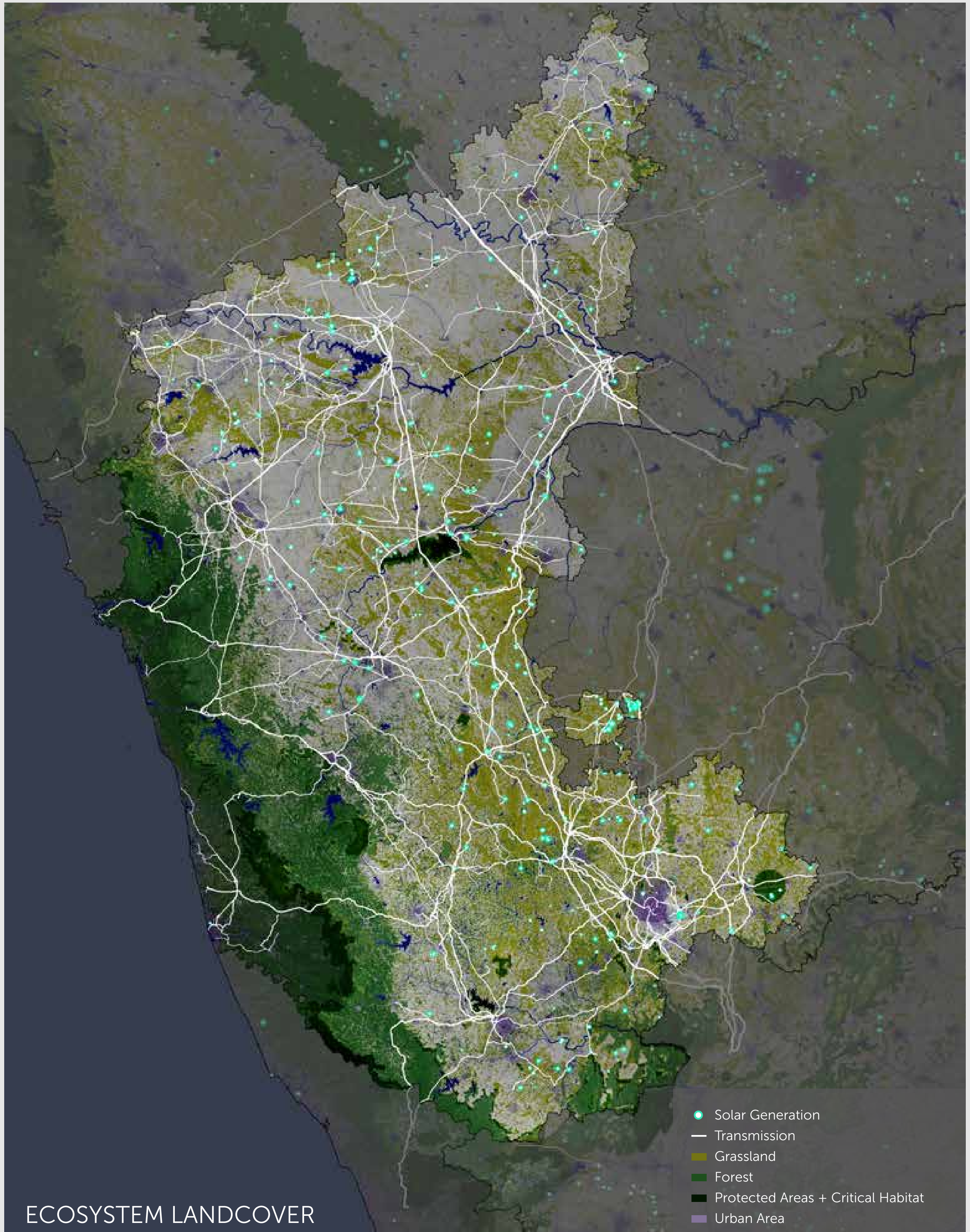


FUTURE SOLAR GROWTH AND LAND USE DEMAND

2050 Solar Generation Projections - 3.93% CAGR						
Scenario	**Annual Generation (TWh)**	**Solar Share**	**Total Solar Generation (TWh)**	**Utility Scale Solar Share**	**Utility Scale Solar Generation (TWh)**	**Utility Scale Solar Capacity (GW)**
High Renewables (URES)	269.4	65%	175.11	85.0%	148.8435	80.9
No Fossil (NFS)		76%	204.744		174.0324	94.6

Future Solar Growth and Land Use Demand					
Future Scenario	**Current Solar Capacity**	**2050 Solar Capacity (GW)**	**Solar Capacity Growth (GW)**	**Solar Land Use Demand Growth (ha)**	**Total 2050 Solar Land Use Demand (ha)**
High Renewables (URES)	11.5	80.9	69.5	180,572	209,702
No Fossil (NFS)		94.6	83.1	216,173	245,303





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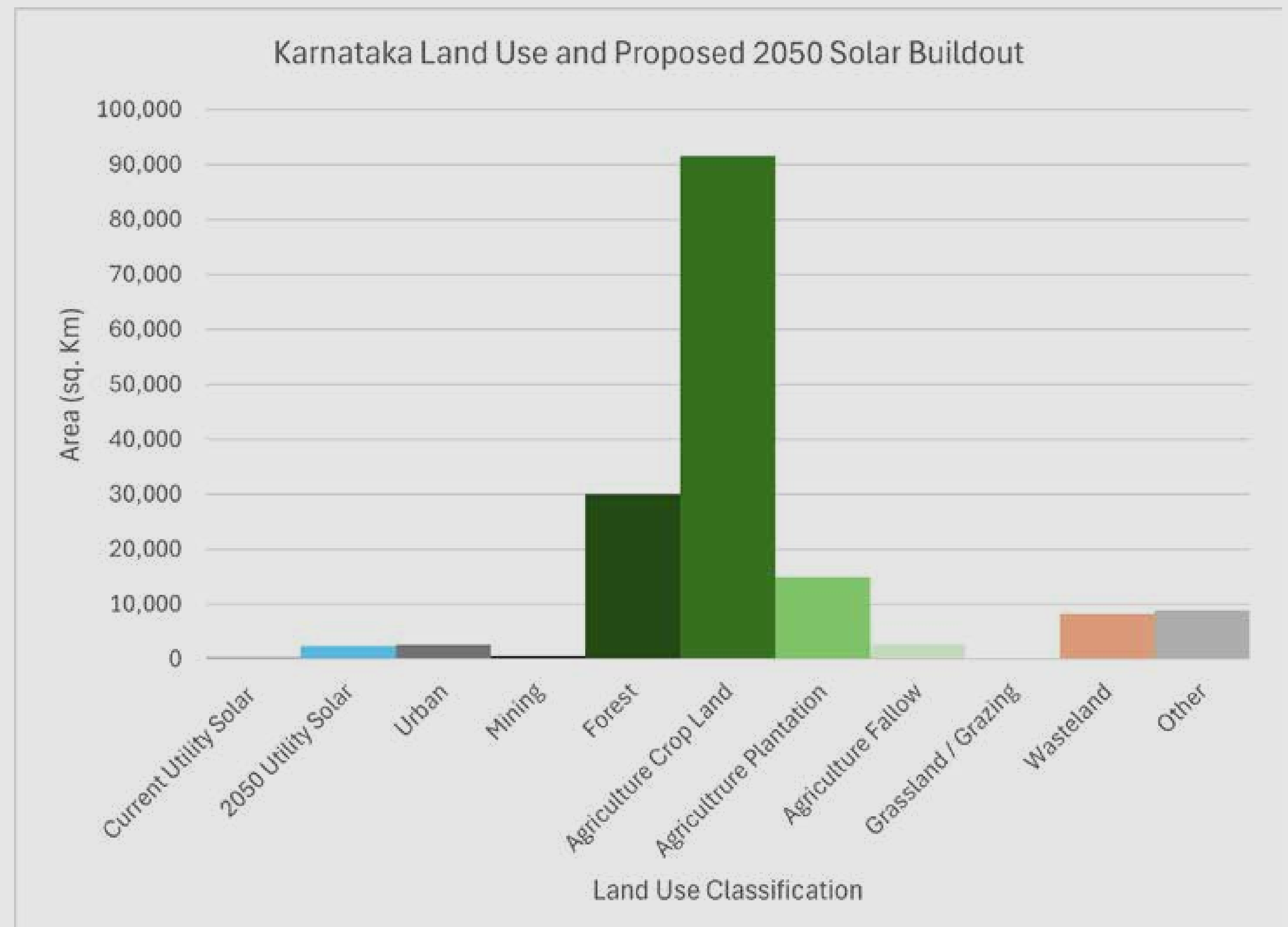

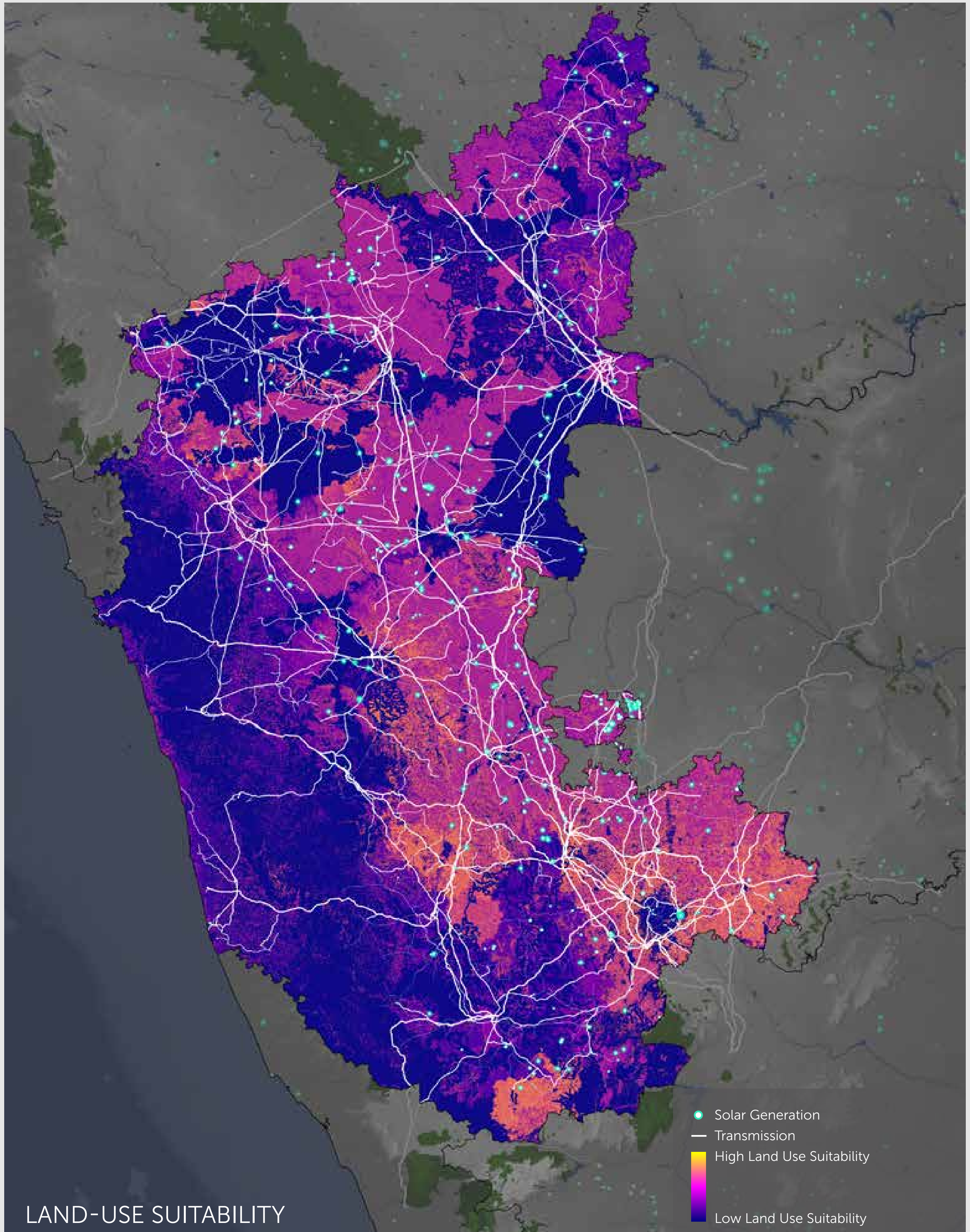

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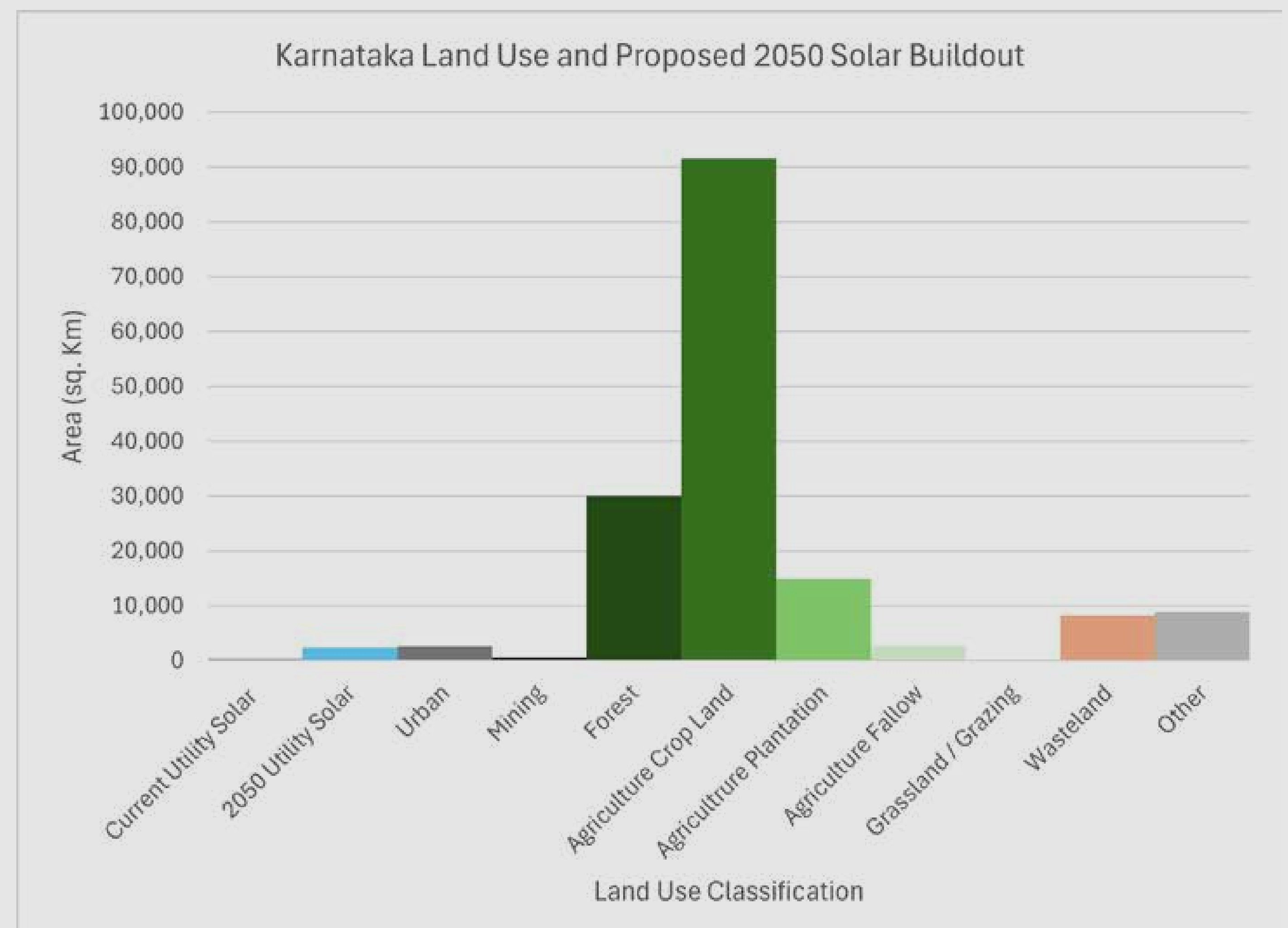
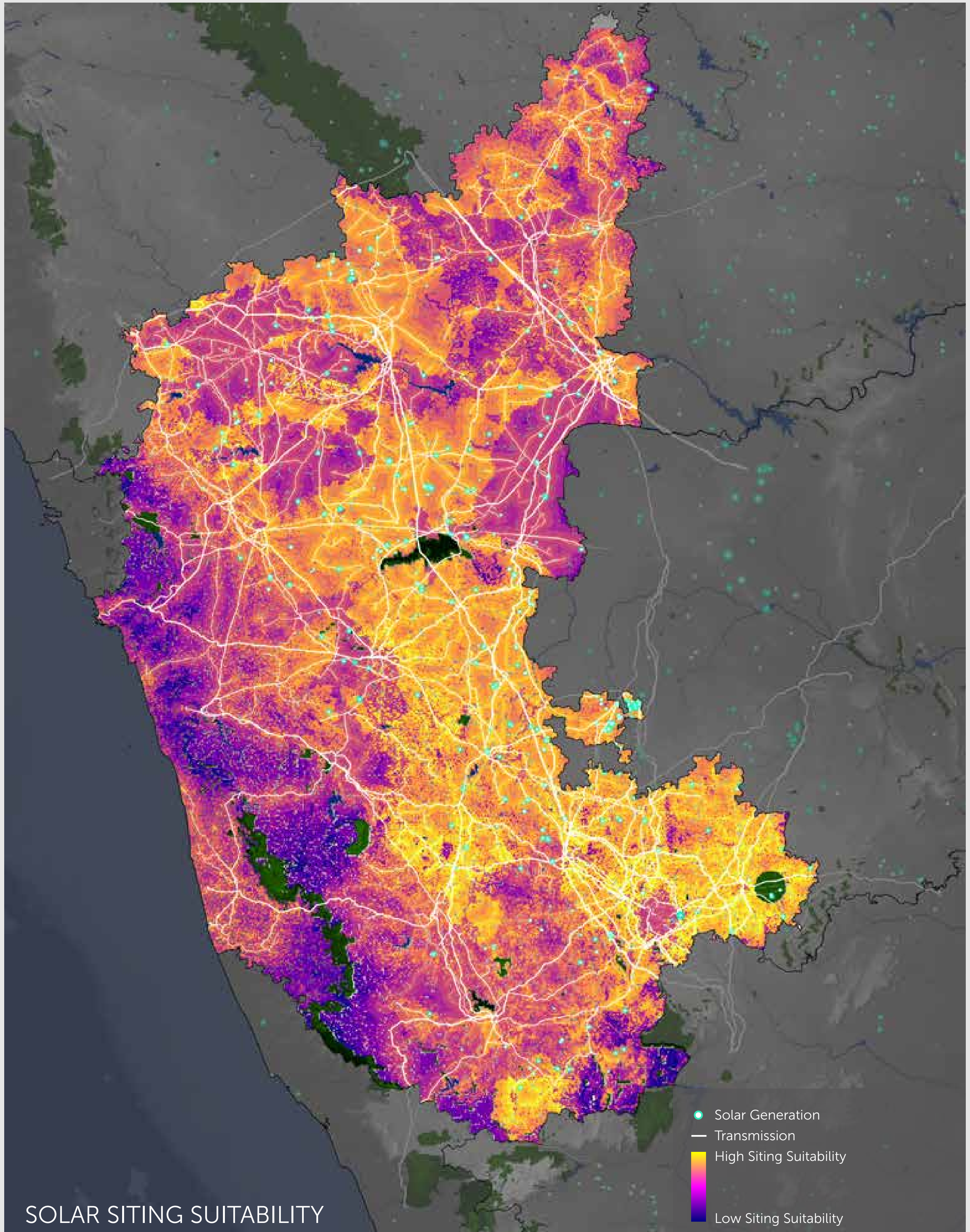
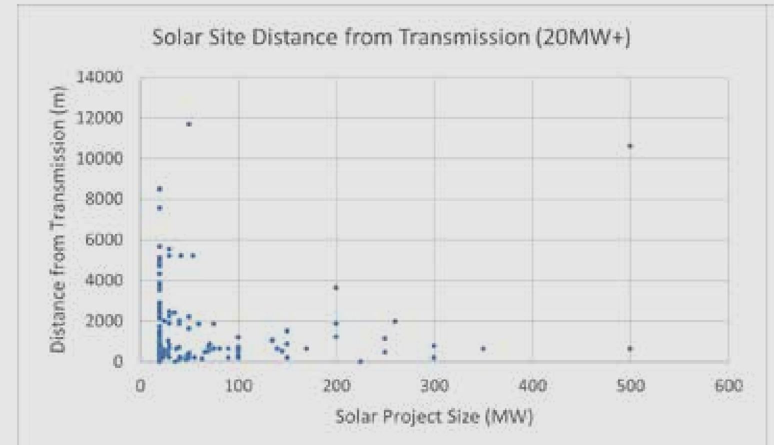
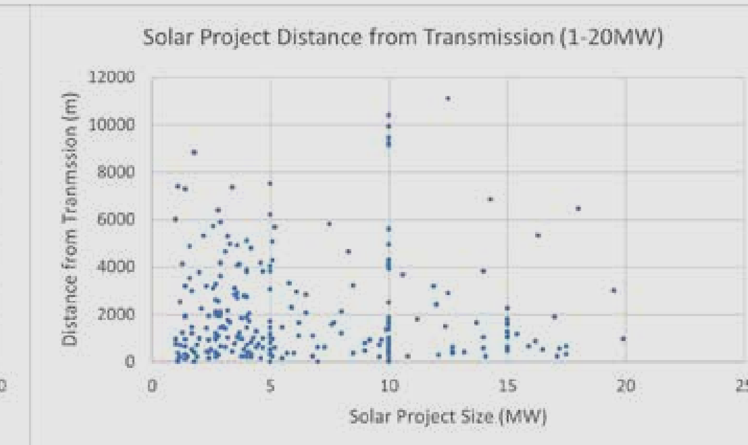
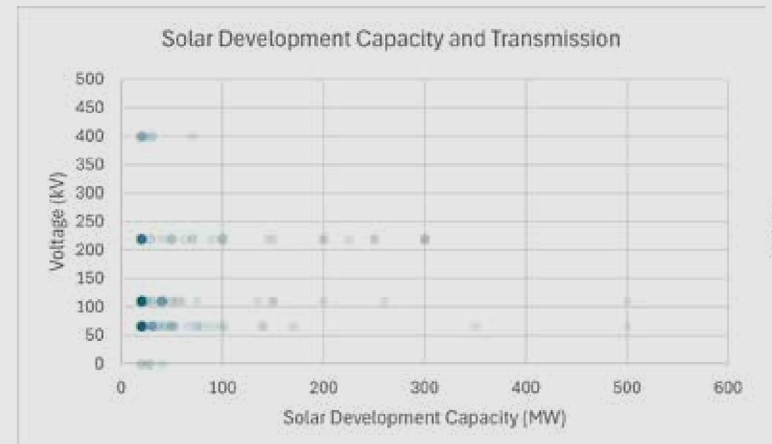


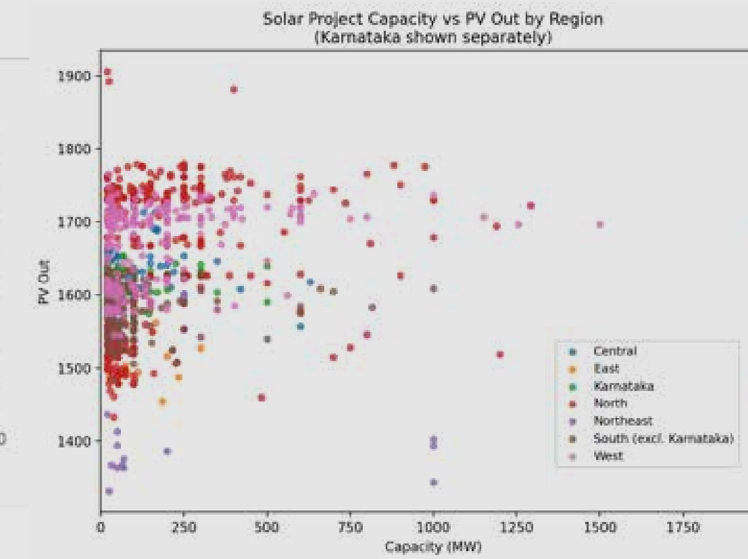


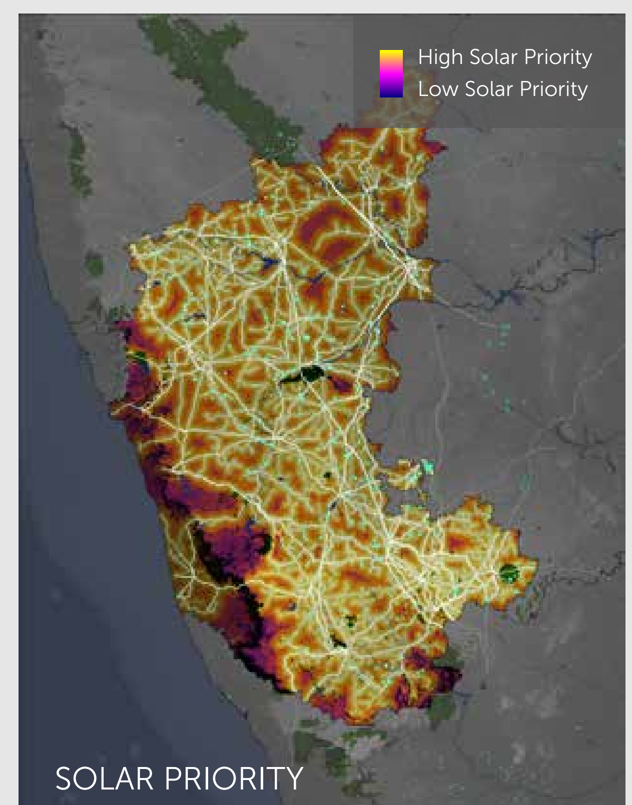
CONSTRAINTS FOR SOLAR DEVELOPMENT

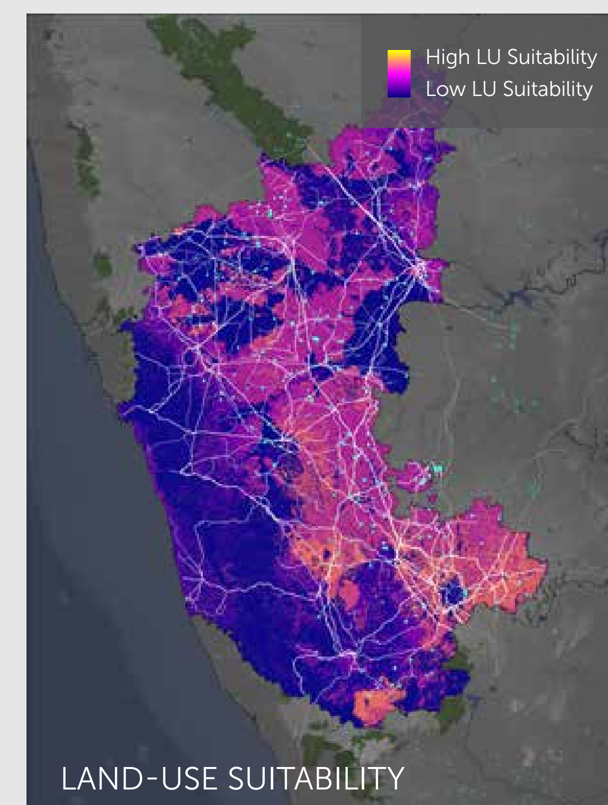












SOCIO-ECONOMIC CONSTRAINTS

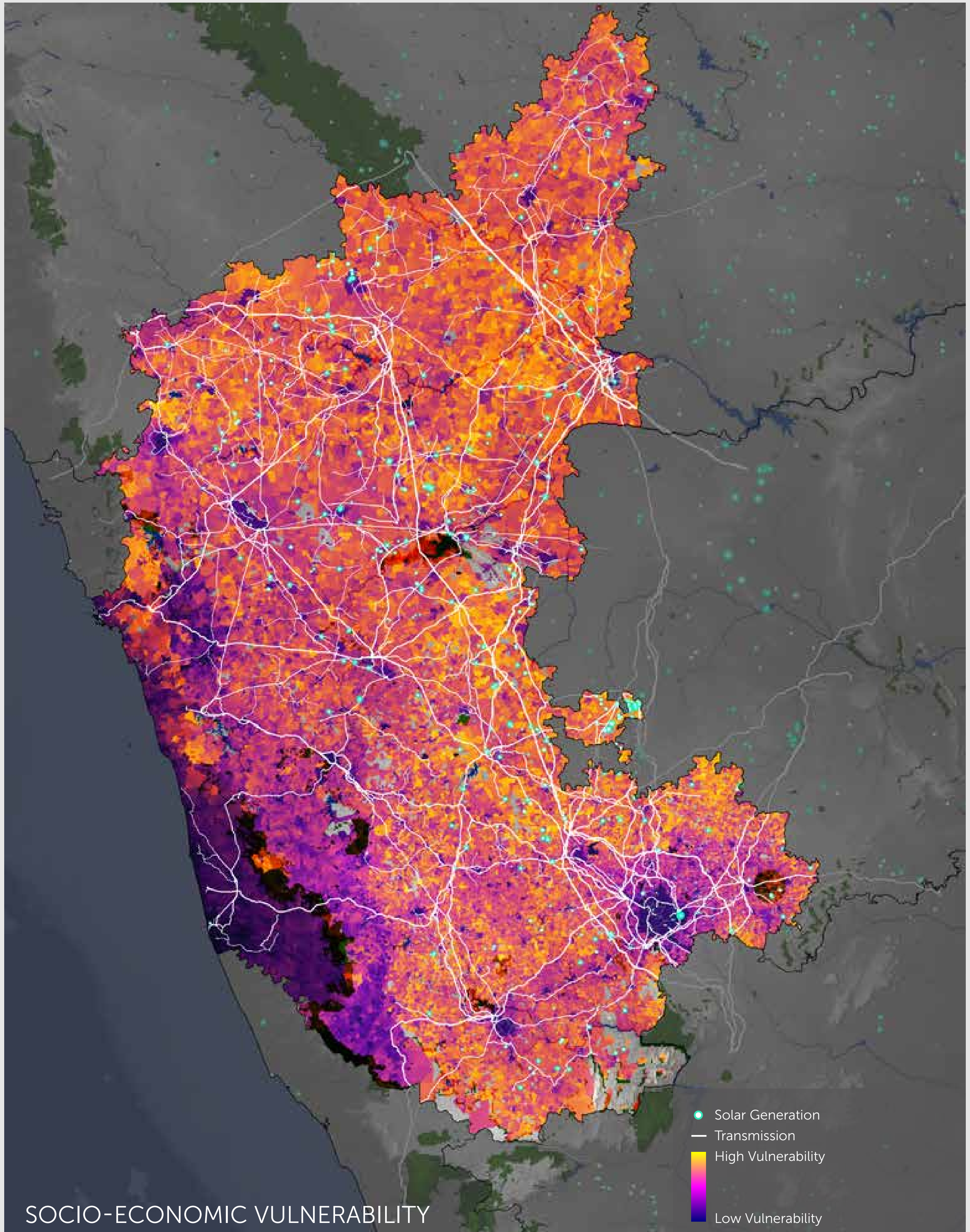
- Communities with high dependence on agricultural labor may have few viable livelihood alternatives if agrarian output declines
- High shares of non-landowning agricultural laborers suggest that land conversion compensation will bypass many of those affected.
- Broader economic vulnerability can further limit households' ability to adapt, compounding barriers to a just transition.

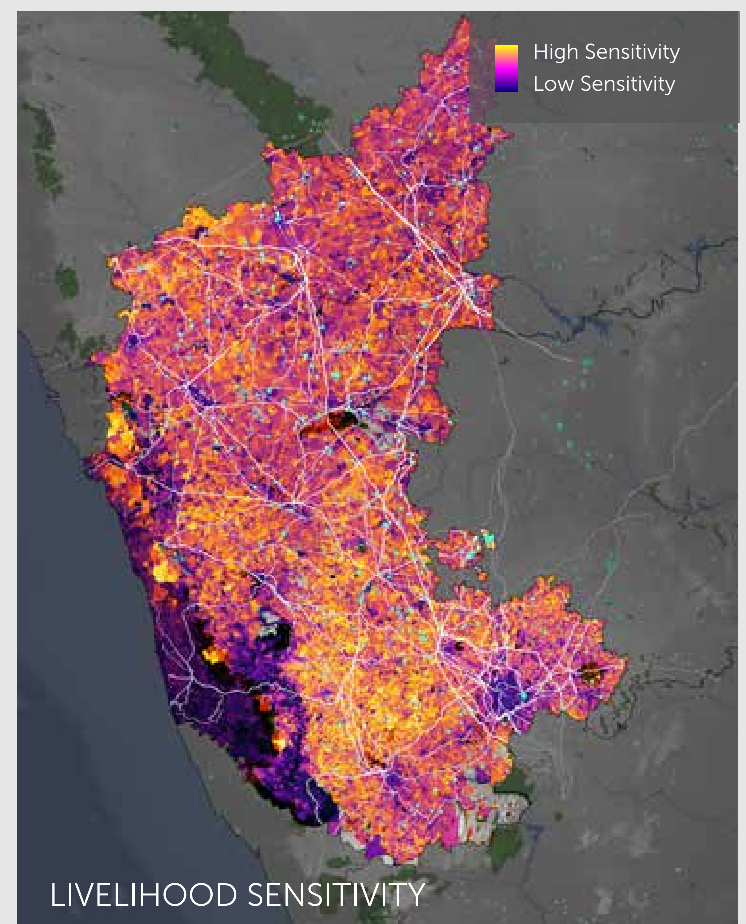
Social Sensitivity

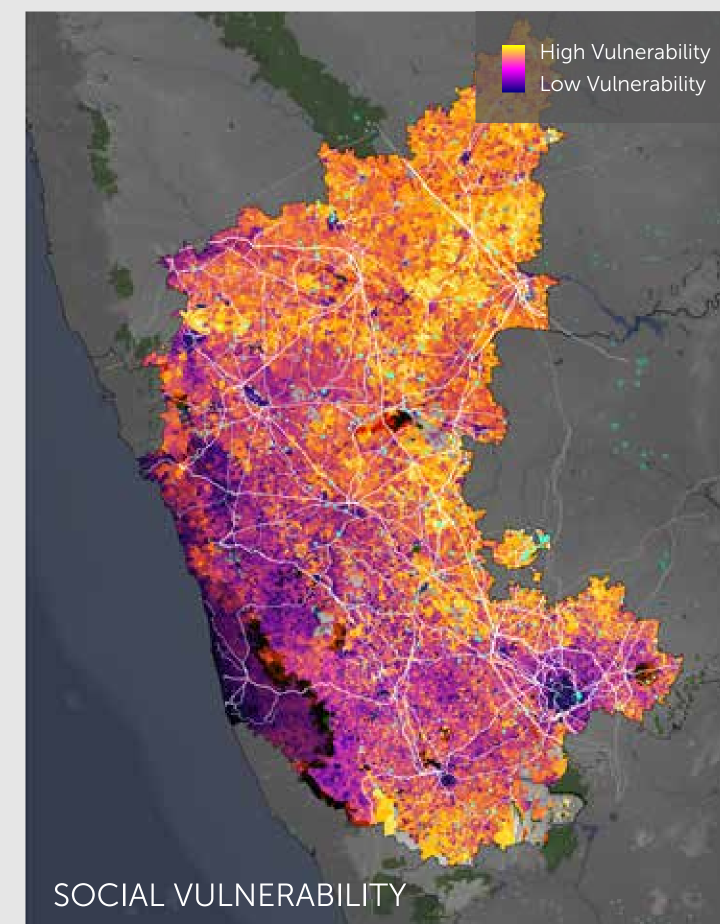
- Scheduled Caste + Tribe
- Literacy Rate
- Households w/o electricity
- Households w/o sanitation
- Households w/o assetsts

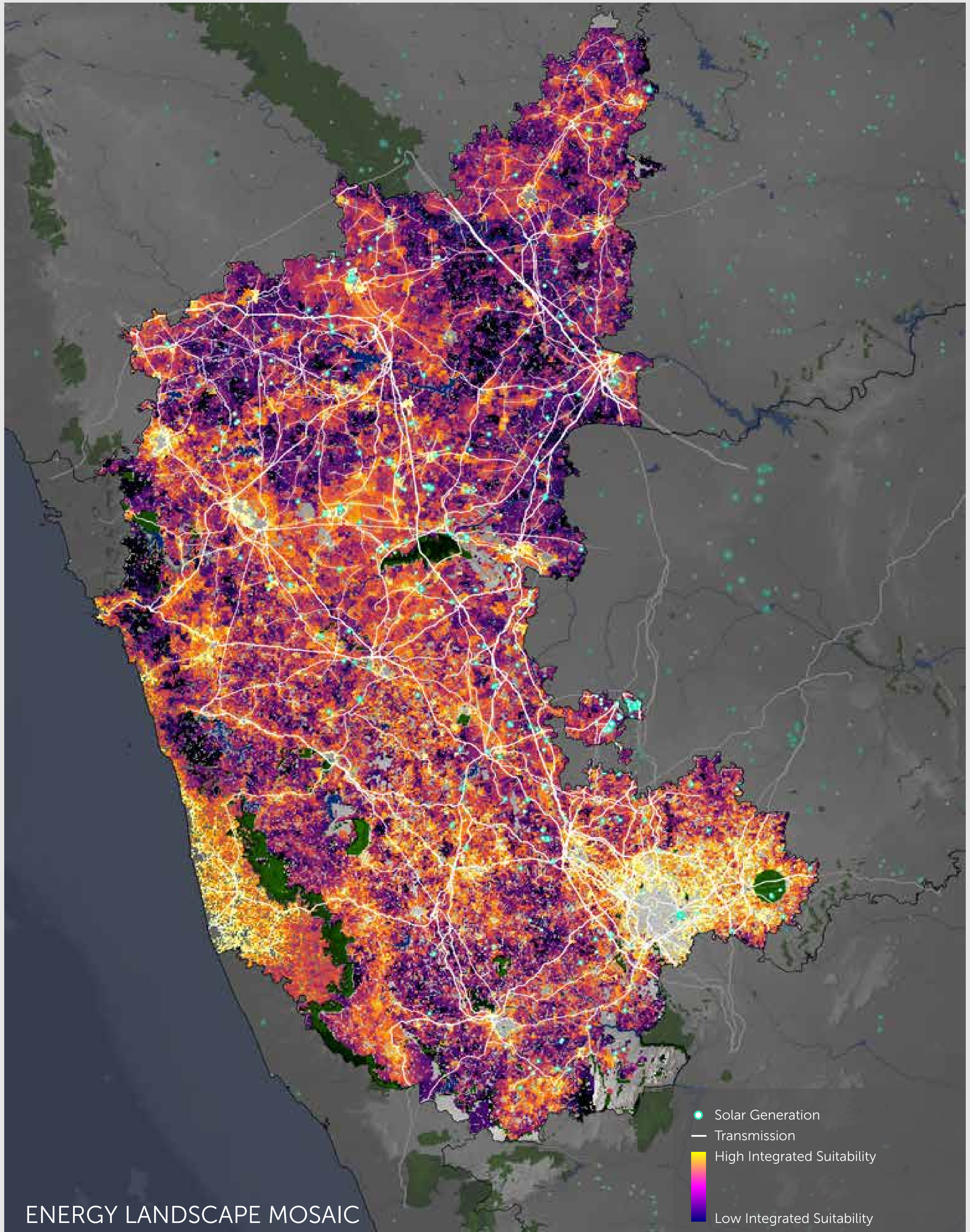
Livelihood Sensitivity

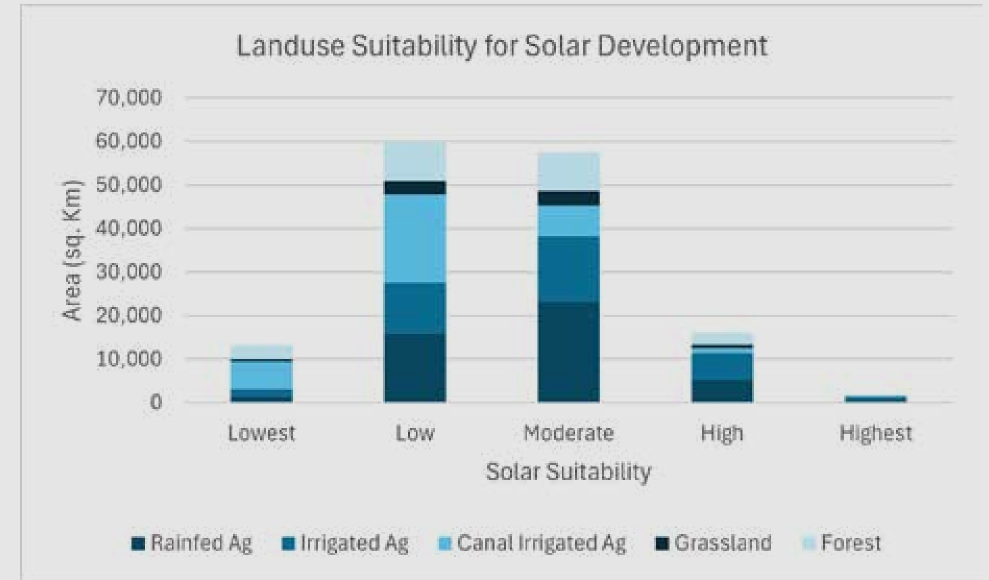
- Cultivators and Agricultural laborers
- Agricultural laborers
- Marginal Agrarian workers



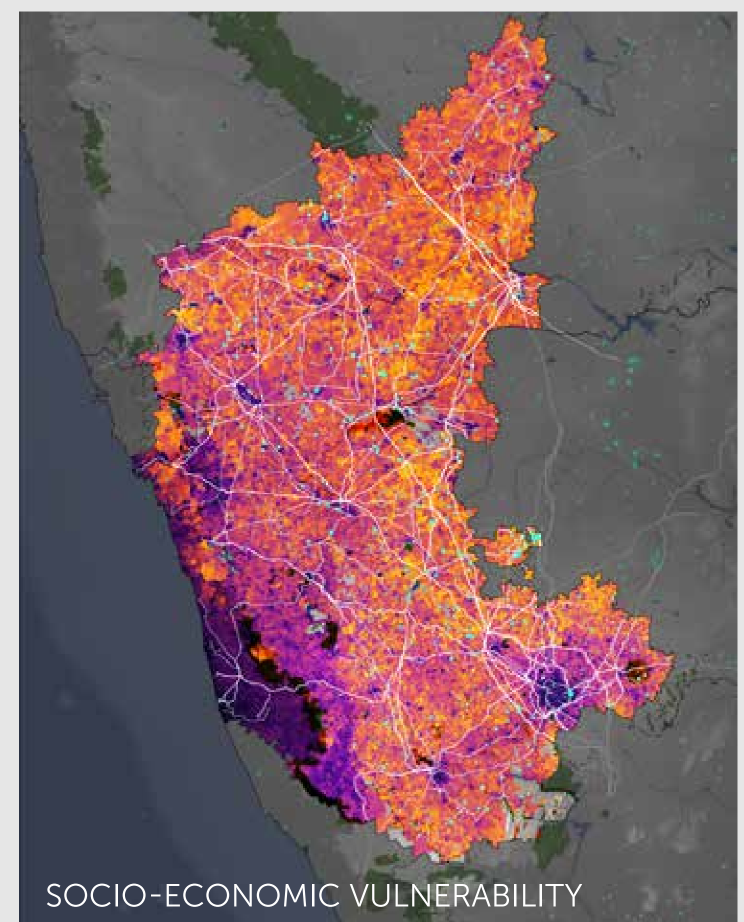


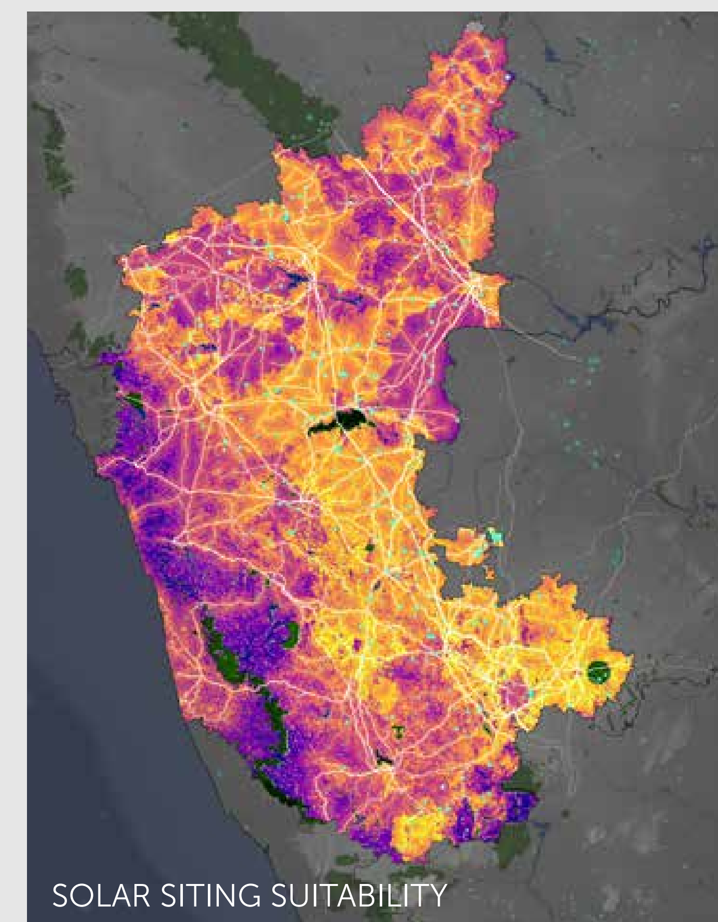


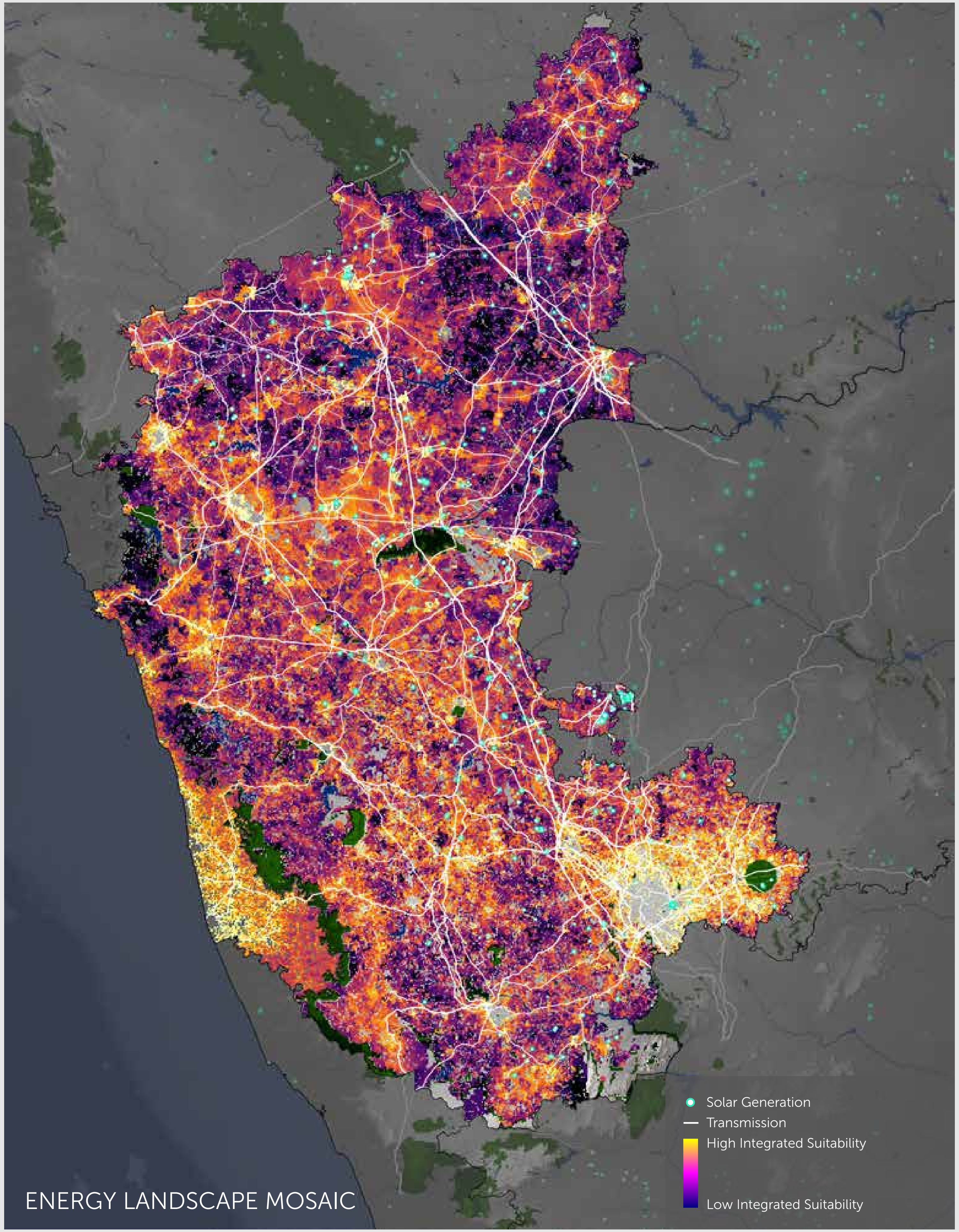


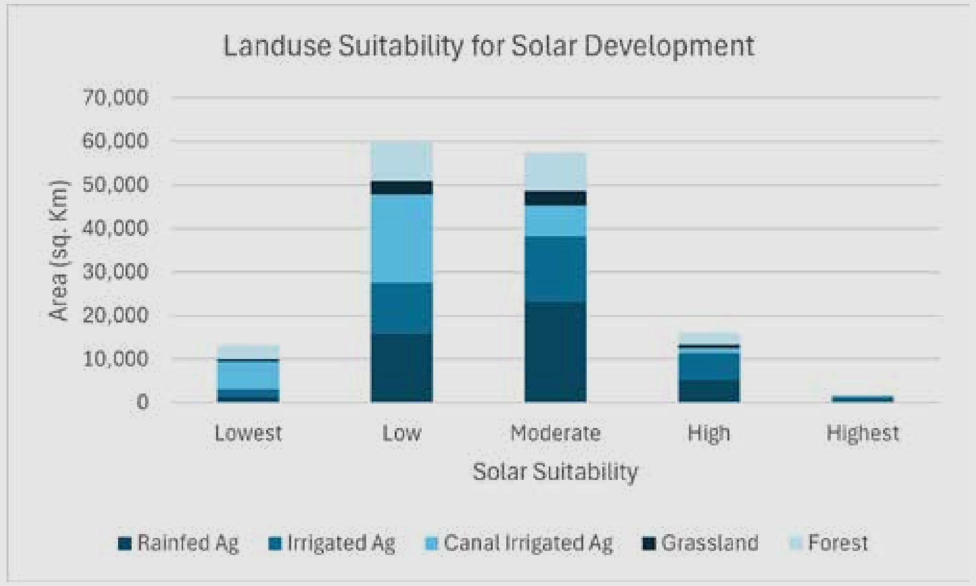


Agricultural Landuse Suitability for Solar Development (sq. Km)					
Land Use	**Lowest**	**Low**	**Moderate**	**High**	**Highest**
Rainfed Ag	1,478	16,047	23,181	5,320	592
Irrigated Ag	1,663	11,465	15,068	6,148	885
Canal Irrigated Ag	6,272	20,293	7,078	1,011	40
Grassland	605	3,073	3,281	865	96
Forest	3,178	8,790	8,844	2,704	237









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- Solar-suitable marginal agrarian land is likely available without endangering vulnerable communities.
- Groundwater-irrigated agrarian land use in regions of over-extraction can provide an opportunity for targeted development.
- The large quantity of surface-irrigated land makes it a candidate for limited conversion.
- Diversifying solar project size can better match development intensity to landscape context.
- Smaller-scale solar may be more appropriate in socially and economically vulnerable agrarian communities.

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Central Ground Water Board. 2023. Dynamic Ground Water Resources of India, 2023. Faridabad: Ministry of Jal Shakti, Government of India.

Energy Sector Management Assistance Program. 2019. Global Solar Atlas 2.0: Technical Report. Washington, DC: World Bank.

Energy Sector Management Assistance Program. 2020. Global Photovoltaic Power Potential by Country. Washington, DC: World Bank.

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Van Tricht, K., J. Degerickx, S. Gilliams, D. Zanaga, M. Battude, A. Grosu, J. Brombacher, M. Lesiv, J. C. L. Bayas, S. Karanam, S. Fritz, I. Becker-Reshef, B. Franch, B. Mollà-Bononad, H. Boogaard, A. K. Pratihast, and Z. Szantoi. 2023. “WorldCereal: A Dynamic Open-Source System for Global-Scale, Seasonal, and Reproducible Crop and Irrigation Mapping.” Earth System Science Data 15: 5491–5515. https://doi.org/10.5194/essd-15-5491-2023
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ESA WorldCereal 10 m 2021 v100

Van Tricht, K., J. Degerickx, S. Gilliams, D. Zanaga, M. Savinaud, M. Battude, R. Buguet de Chargère, G. Dubreule, A. Grosu, J. Brombacher, H. Pelgrum, M. Lesiv, J. C. L. Bayas, S. Karanam, S. Fritz, I. Becker-Reshef, B. Franch, B. M. Cintas, H. Boogaard, A. K. Pratihast, L. Kucera, and Z. Szantoi. 2023. ESA WorldCereal 10 m 2021 v100. Zenodo. https://doi.org/10.5281/zenodo.7875104

Used to identify temporary cropland and distinguish irrigated and rainfed agricultural areas. This was one of the core agricultural land-use layers for screening solar suitability against agrarian land-use conflict.

Landsat-Derived Global Rainfed and Irrigated-Cropland Product 30 m, Version 1

NASA Land Processes Distributed Active Archive Center. 2023. Landsat-Derived Global Rainfed and Irrigated-Cropland Product 30 m, Version 1. Sioux Falls, SD: NASA LP DAAC.

Used, or considered, as an additional irrigated/rainfed cropland overlay. In the project workflow, this layer helped distinguish agricultural land by irrigation dependence, including irrigated, rainfed, non-agricultural, and nodata/water classes.

Global Solar Atlas PVOUT Raster

Energy Sector Management Assistance Program. 2019. Global Solar Atlas 2.0. Washington, DC: World Bank.
Used to represent photovoltaic power potential across Karnataka. PVOUT values were used as a solar resource criterion and joined or sampled to solar project locations and suitability surfaces.

Global Solar Power Tracker

Global Energy Monitor. 2026. Global Solar Power Tracker, February 2026 Release. Global Energy Monitor.

Used as the facility-level solar development dataset, including project locations, capacity, status, and scale. In the analysis, this supported mapping existing and planned solar development patterns and comparing project size with transmission proximity and land-use context.

India Land Use / Land Cover

National Remote Sensing Centre. 2018. India Land Use Land Cover. Bhuvan / Natural Resources Census. Hyderabad: National Remote Sensing Centre, Indian Space Research Organisation.

Used as a broad land-cover classification layer for suitability screening. The project used LULC classes to distinguish built-up, agricultural, open, vegetated, and other land-cover categories, with agricultural areas treated cautiously because more specific agricultural layers were also used.

Land Use / Land Cover Analysis: Third Cycle, 1:50,000 Scale, 2015–16

National Remote Sensing Centre. 2019. Land Use / Land Cover Analysis: Third Cycle, 1:50,000 Scale, 2015–16. Hyderabad: National Remote Sensing Centre, Indian Space Research Organisation.

Used or considered as a finer-resolution Bhuvan/NRSC LULC product for land-use suitability and exclusion scoring. This source is especially relevant if the final workflow used the 1:50,000 Bhuvan service rather than the broader India 250K product.

Village/Town-wise Primary Census Abstract, 2011: Karnataka

Office of the Registrar General & Census Commissioner, India. 2011. Village/Town-wise Primary Census Abstract, 2011: Karnataka. New Delhi: Ministry of Home Affairs, Government of India.

Used as the principal village-level demographic and occupational dataset. Variables such as agricultural workers, agricultural labourers, marginal workers, literacy, SC/ST population, and household/service-access indicators supported livelihood sensitivity and social vulnerability metrics.

Mission Antyodaya Survey Data

Ministry of Rural Development, Government of India. 2020–2025. Mission Antyodaya Survey Data. Open Government Data Platform India / eGramSwaraj.
Used or considered for village/community-level infrastructure and deprivation indicators. This source helped supplement Census-derived social vulnerability metrics where accessible village-level service or asset indicators were needed.

Dynamic Ground Water Resources of India Spatial Assessment Units

Central Ground Water Board. 2023. Dynamic Ground Water Resources of India, 2023. Faridabad: Ministry of Jal Shakti, Government of India.
Used to classify groundwater-stress context, including over-exploited, critical, semi-critical, and safe assessment units. In the project logic, groundwater-stressed irrigated agricultural areas were treated differently from other agricultural lands because solar conversion could reduce pressure on over-extracted groundwater systems.

NASA Shuttle Radar Topography Mission Global 1 Arc Second

NASA Jet Propulsion Laboratory. 2013. NASA Shuttle Radar Topography Mission Global 1 Arc Second. NASA EOSDIS Land Processes Distributed Active Archive Center.

Used, if this was the DEM source, to derive slope suitability. Slope was incorporated as a physical constraint for solar siting, with flatter terrain generally treated as more suitable.

Karnataka Transmission Lines and Voltage Attributes

Open Street Map

Used to calculate transmission proximity, assign nearest-line voltage to solar projects, and evaluate whether transmission access helps explain existing solar project distribution. The exact citation should be updated after confirming whether the layer came from VEDAS/ISRO, KPTCL, OpenStreetMap, CEA, or an ArcGIS REST service.