Annexures

[Unlocking India's RE and Green Hydrogen Potential](#)
[An Assessment of Land, Water, and Climate Nexus](#)

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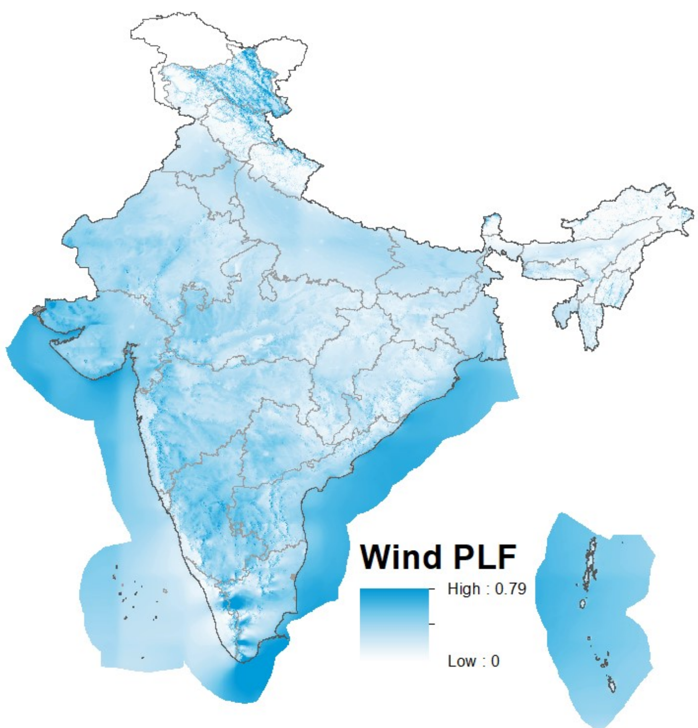
Annexure I. Renewable energy plant load factors

The solar and wind plant load factors across various geographies in India are obtained from the Global Solar Atlas (Global Solar Atlas 2023) and Global Wind Atlas (Global Wind Atlas 2023), respectively. The raster size in the Atlas for solar plant load factor (PLF) is 833 m x 833 m while it is 250 m x 250 m for wind power. The solar PLF is based on photovoltaic power output, while the wind PLF is obtained for an International Electrotechnical Commission (IEC) Class III at a hub height of 100m height. In the assessment, we only consider solar and wind PLFs for areas within India's geographical control.

Figure A1 shows the plot of variation in wind PLFs across India. It can be seen that a few pockets in Tamil Nadu have PLFs higher than 60 - 70 per cent. Generally, only states along the western ghats and pockets in Madhya Pradesh, Gujarat and Rajasthan have good wind potential. The northern and eastern India do not have good wind potential. Figure A1 also indicates the offshore wind potential within India's Exclusive Economic Zone (EEZ) (The Territorial Waters, Continental Shelf, Exclusive Economic Zone and other Maritime Zones Act 1976). Offshore areas near southern India and Gujarat have good wind PLF.

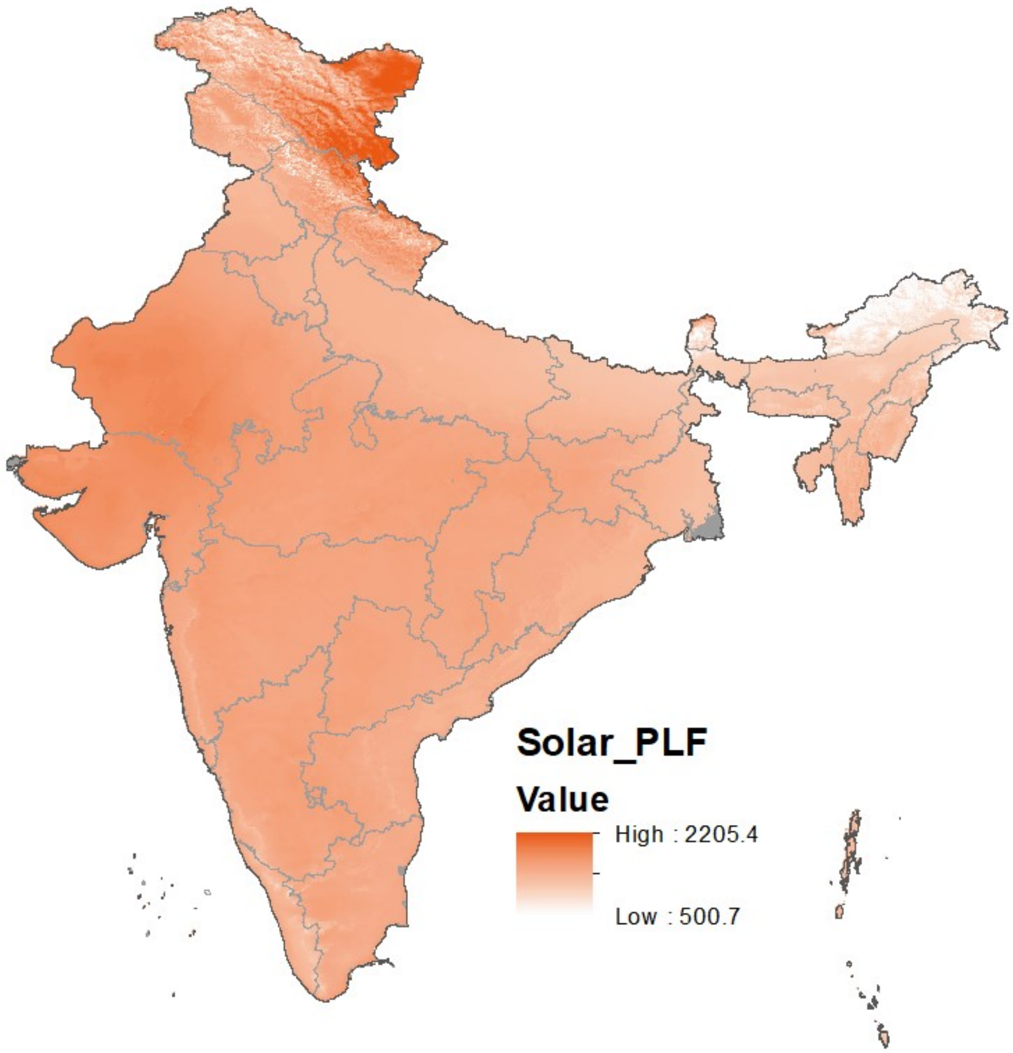
Figure A1 Wind capacity is concentrated in the western and southern India 100m



Source: "Global Wind Atlas." Global Wind Atlas. Accessed January 10, 2023. https://globalwindatlas.info/en/.

Figure A2 shows the variation in solar PLF across India. Generally, it is seen that the solar PLF does not significantly vary across the country although a few pockets in Rajasthan and Ladakh have slightly higher solar PLF than the rest of the country. Generally, western and southern India have better solar resource availability compared to northern and eastern India.

Figure A2 Western and southern India has good solar resource availability



Source: "Global Solar Atlas." Global Solar Atlas. Accessed January 10, 2023. https://globalsolaratlas.

Annexure II. Land Use Land Cover (LULC) considerations for the study

Land characteristics form an integral part of decision-making for RE projects. The LULC information is obtained from Environmental Systems Research Institute (ESRI 2023). The LULC categorisation is discussed in Table A1. The definitions of various land types are directly adopted from literature (ESRI 2023).

Table A1: Study considers all LULC categories

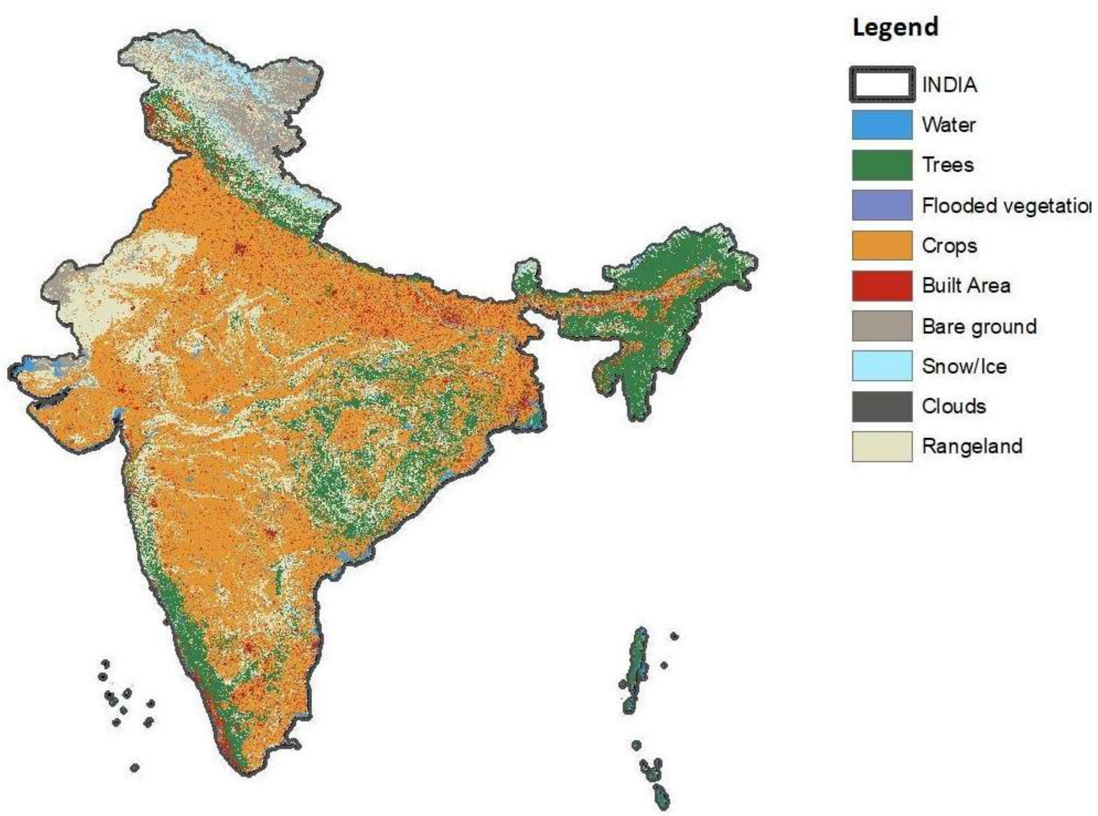
Sr. No.	Attribute	Consideration
1	Water	Areas where water is predominantly present throughout the year are considered to have good water resources. Areas with sporadic or ephemeral water availability are excluded from this categorisation. We assume that land mass considered under water category has little to no or sparse vegetation. Further, land categorised as water has no rock, crop or built-up features like docks. Examples of water resources are rivers, ponds, lakes, oceans and flooded salt plains.
2	Trees	Any significant clustering of tall (~15-m or higher) dense vegetation, typically with a closed or dense canopy are categorised as trees. Examples are wooded vegetation, clusters of dense tall vegetation within plantations, swamp or mangroves. Dense/tall vegetation with ephemeral water or canopy too thick to detect water underneath are considered as mangroves and categorised as trees.
3	Flooded vegetation	Areas with any type of vegetation with obvious intermixing of water throughout a majority of the year are categorised as flooded vegetation. This includes land mass with seasonally flooded area that is a mix of grass/shrub/trees/bare ground. Examples of area with flooded vegetation include flooded mangroves, emergent vegetation, rice paddies and other heavily irrigated and inundated agriculture.
4	Crops	Land mass under crop land considers human planted/plotted cereals, grasses, and crops not at tree height. Examples include plantations of corn, wheat, soy, and fallow plots of structured land.
5	Built-up	Built up area includes human made structures, major road and rail networks, large homogenous impervious surfaces including parking structures, office buildings and residential housing. Examples include houses, dense villages / towns / cities, paved roads, and asphalt.
6	Bare ground	Bare ground category includes land mass of rock or soil with very sparse to no vegetation for the entire year and large areas of sand and deserts with little to no vegetation. Examples include exposed rock or soil, desert and sand dunes, dry salt flats/pans, dried lake beds and mines.

7	Snow/ice	Large homogenous areas of permanent snow or ice, typically only in mountain areas or high latitudes are categorised as snow/ice. Examples include glaciers, permanent snowpack and snow fields.
8	Cloud cover	Land area where no land cover information is available due to persistent cloud cover is categorised under cloud cover.
9	Rangeland	Land area covered in homogenous grasses with little to no taller vegetation, wild cereals and grasses with no obvious human plotting (i.e., not a plotted field) are classified as range land. Examples include natural meadows and fields with sparse to no tree cover, open savanna with few to no trees, parks/golf courses/lawns and pastures. Further, a mix of small clusters of plants or single plants dispersed on a landscape that shows exposed soil or rock, scrub-filled clearings within dense forests that are clearly not taller than trees are also categorised as range land. Examples include moderate to sparse cover of bushes, shrubs and tufts of grass, savannas with very sparse grasses, trees or other plants.

Source: ESRI. 2023. Environmental Systems Research Institute. 15 January. Accessed September 14, 2023. https://www.esri.com/en-us/home.

Land mass categorised as built-up area, snow, water, flooded vegetation, and trees are excluded from considerations for setting up RE plants as any construction activity is not possible or desirable on these land types. Cloud cover represents no information thus exclusion of it for considering RE potential. In our analysis, cloud cover represents 0.3 per cent of the Indian landmass. The spatial information regarding various land types is gathered at 10 m by 10 m raster level and used for assessing the RE potential in the country. Figure A3 shows the distribution of land mass in India across these categories. As solar power has a high land footprint, croplands are excluded from landmass for calculating solar potential. However, we consider that wind turbines can be installed in crop lands.

Figure A3 India's land use land cover division



Source: "GIS Mapping Software, Location Intelligence & Spatial Analytics." ESRI. Accessed January 10, 2023. https://www.esri.com/en-us/home.

Figure A4 shows the distribution of land mass in India across the various LULC categories. Cropland occupies 46 per cent of total land mass in India followed by rangeland and tree cover. Bare ground is only 5 per cent of the total land mass. It should be noted that solar power can be installed only in bare land and range land while wind power can be additionally installed in cropland as it has a lower land footprint compared to solar.

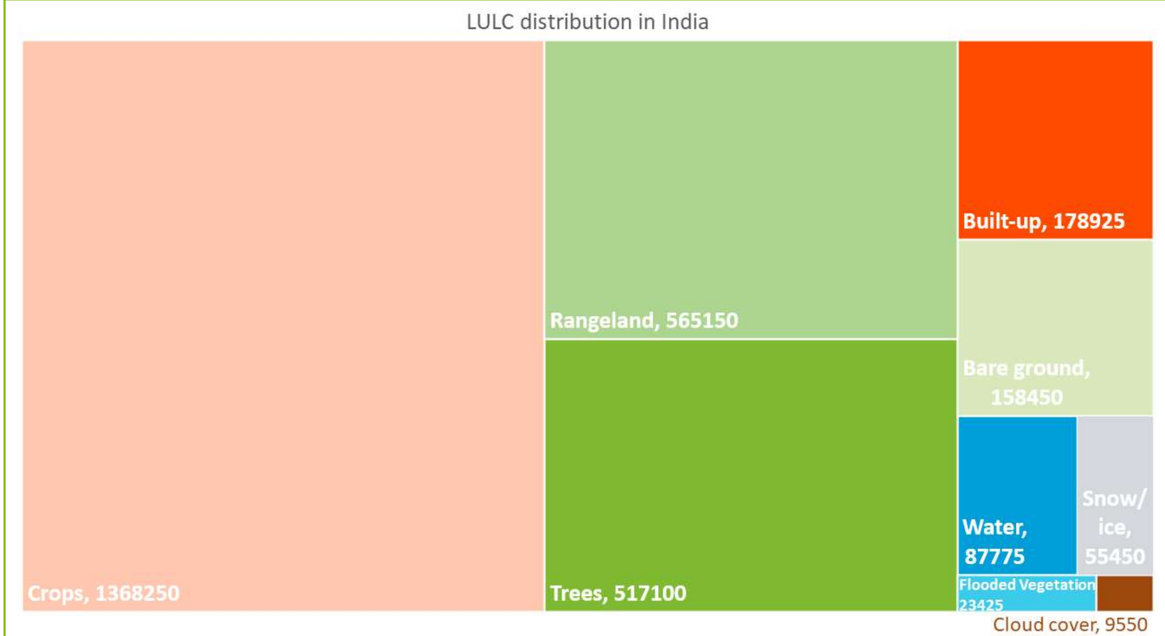
Table A2: LULC categorisation in India

Sr. No.	LULC category	Category considered for solar potential (Yes/No)	Category considered for wind potential (Yes/No)	Area in sq.km.	Percentage
1	Water	No	No	87775	3.0%
2	Trees	No	No	517100	17.4%
3	Flooded vegetation	No	No	23425	0.8%
4	Crops	No	Yes	1368250	46.0%

5	Built-up	No	No	178925	6.0%
6	Bare ground	Yes	Yes	158450	5.3%
7	Snow/ice	No	No	55450	1.9%
8	Cloud cover	No	No	9550	0.3%
9	Rangeland	Yes	Yes	565150	19.0%

Source: Authors' analysis

Figure A4 Maximum landmass of India is under croplands (46 per cent) and only 24 per cent of the remaining land can be considered for setting up of RE plants



Source: Authors' analysis

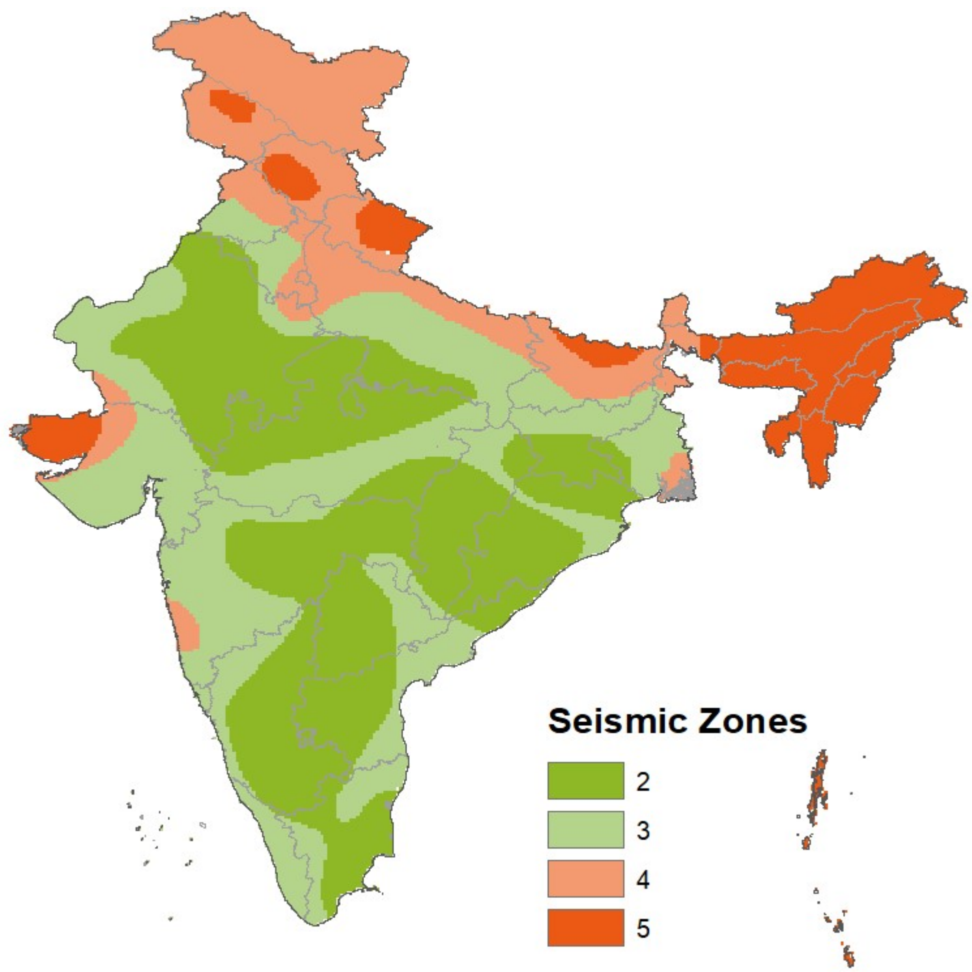
Annexure III. Constraints for setting up RE and GH2 projects

This annexure discusses and quantifies various constraints for setting up RE and GH2 projects in the country. As discussed in the main body of the report, the constraints considered for realising the RE and GH2 potential in the country are seismic zones, eco-sensitive and military no-go zones, areas with climate risk, gas pipeline connectivity, population density and land conflicts.

a) Earthquake-prone zones

The seismic zones in India are identified based on information provided by (WCDM 2023). In India, seismic zones are divided based on their risk exposure to earthquakes measured on a scale of 2 to 5 (5 being the most earthquake-prone zone). India does not have any seismic zone 1. The seismic zones are indicated in Figure A5. About ~ 70 per cent of India's land mass is in seismic zone 2 and 3 indicating that RE and GH2 projects are less susceptible to seismic threats.

Figure A5 A significant land mass in India lies in low seismic zone



Source: "World Congress on Disaster Management." 6th WCDM 2023. Accessed January 10, 2023. https://www.wcdm.co.in/.

b) No-Go Zones

No-go zones in India include eco-sensitive areas like national parks and strategic zones like military areas (DGH 2020). We assume that RE and GH2 projects cannot be commissioned in the No-Go zones. Consequently, no-go zones are an exclusion parameter and land mass under the no-go zones are excluded for estimating the RE potential in the country. Our estimations show that 2,36,475 sq. km. (7.1 per cent for the India land mass) is under eco-sensitive and no-go zones. Further, 4,37,300 sq. km. within 12 nautical miles from the coast is under eco-sensitive or military areas.

Figure A6 India's eco-sensitive and military no-go areas occupy 7.1 per cent of India's land mass

Source: DGH. 2020. India's hydrocarbon outlook. New Delhi: Directorate general of hydrocarbon. n.d. Directorate of Economics and Statistics, Government of India. Accessed February 15, 2023. https://aps.dac.gov.in/LUS/Index.htm.

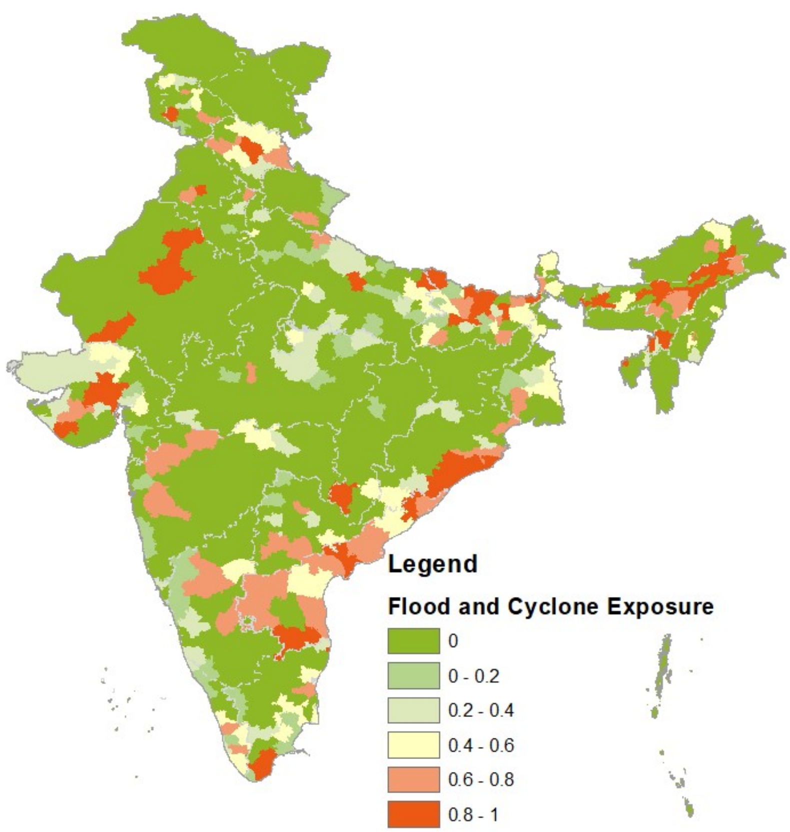
c) Climate risk exposure

Climate risk exposure will be a critical factor in determining the locations of RE and GH2 projects. It will also impact the LCOE and LCOH primarily due to higher premiums on insurance. The frequency and intensity of extreme events and their associated risks are used to identify land mass with higher exposure to climate risk. The climate risk index considers flood and cyclones as potential risk for RE and GH2 projects. The climate risk index is a normalised scoring for extreme weather events on a scale of 0-1. A score less than 0.2 is low exposure, 0.2-0.6 is moderate exposure and more than 0.6 is high exposure. The index helps demarcate districts prone to floods or cyclones.

The climate risk index (Mohanty and Wadhwan 2021) has been developed by examining the frequency and intensity of hydro-met disasters and the pattern of associated events. The index has also analysed the climate impacts for 50 years (1970–2019) and the shifts in trends in climate events across the country.

Figure A7 shows the exposure to floods and cyclones across major districts in India. Western Rajasthan and districts in Maharashtra, Karnataka, Andhra Pradesh and Odisha experience floods and cyclones. North India and non-coastal districts in the east have comparatively low climate risk index and are less susceptible to flood and cyclones.

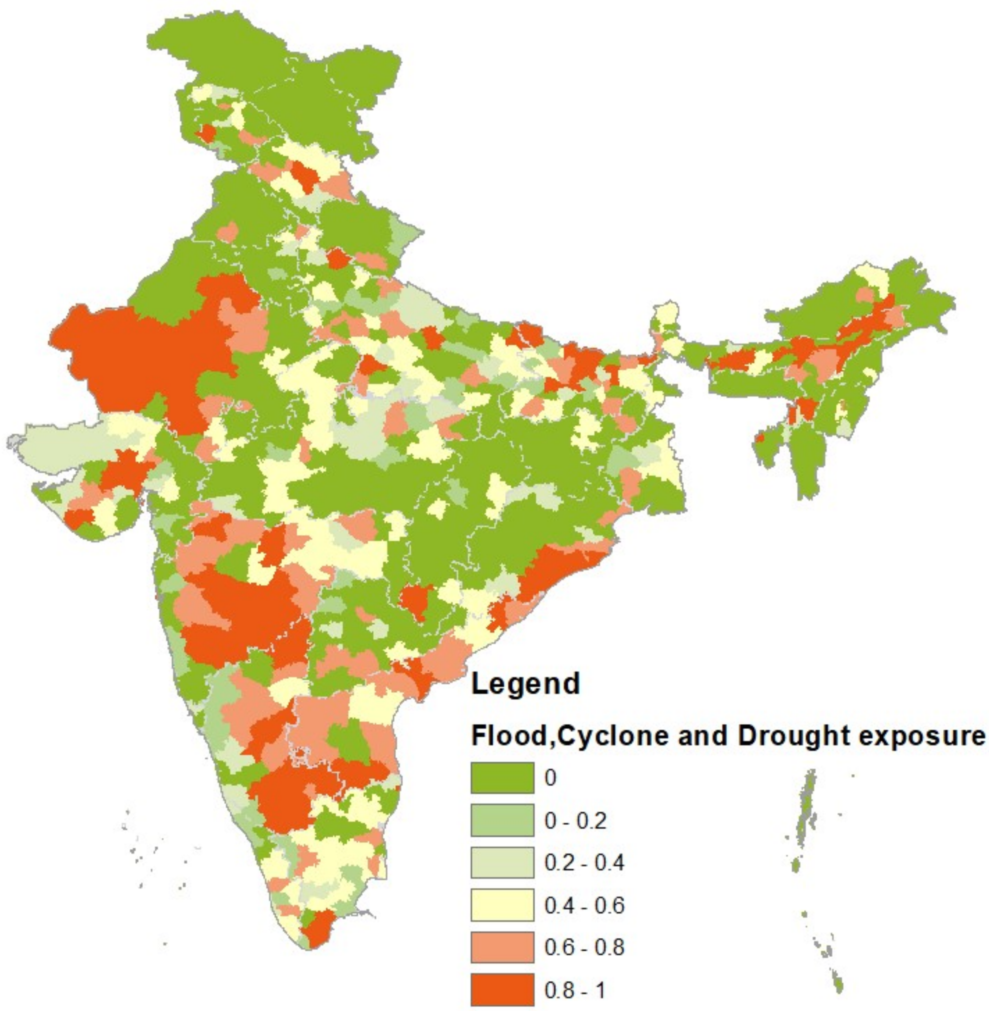
Figure A7 India's exposure to floods and cyclones



Source: Mohanty, Abinash, and Shreya Wadhwan. 2021. Mapping India's Climate Vulnerability - A district level assessment. Report, New Delhi: Council on Energy, Environment and Water.

Figure A8 shows India's exposure to floods, cyclones and droughts. A significant area in western Rajasthan with good solar potential and areas on the west coast along the Sahyadris that has good wind potential faces significant threat from various climate-related events. A few districts on the east coast are also susceptible to disruptions due to climate change.

Figure A8 India's exposure to floods, cyclones and droughts



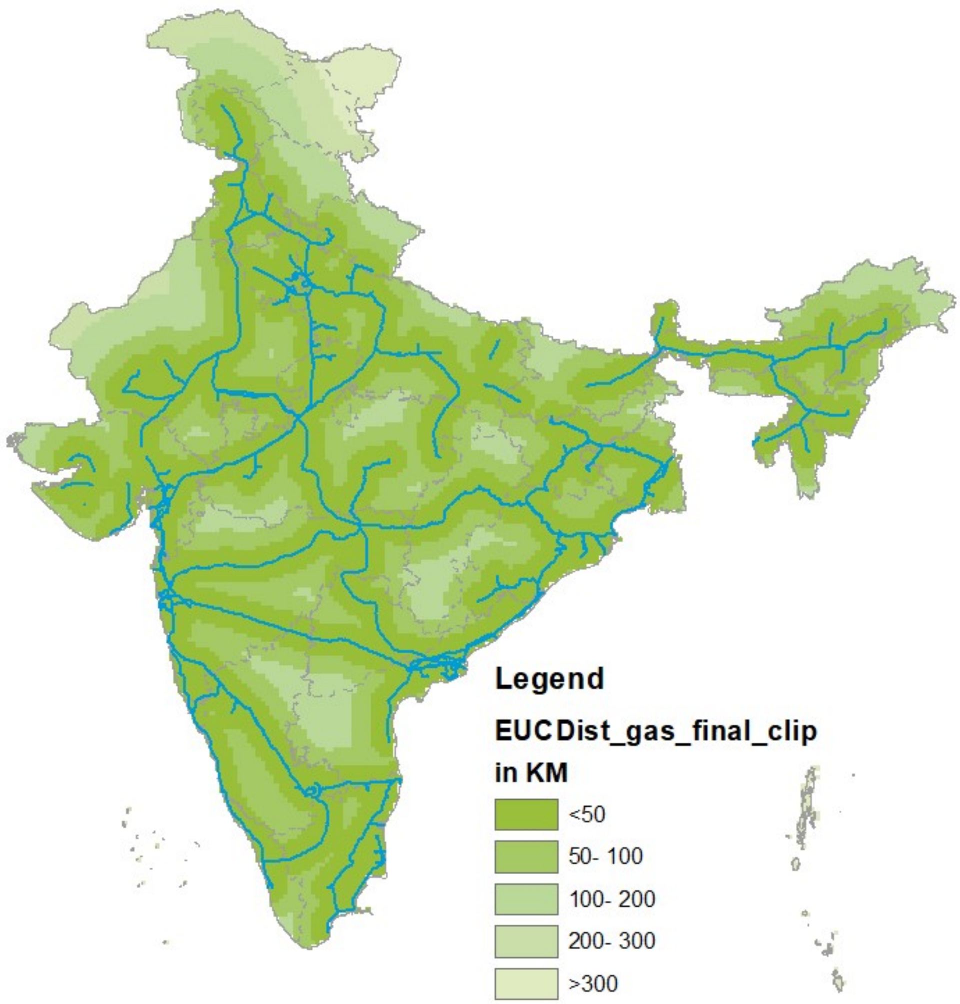
Source: Mohanty, Abinash, and Shreya Wadhwan. 2021. Mapping India's Climate Vulnerability - A district level assessment. Report, New Delhi: Council on Energy, Environment and Water.

d) Gas pipelines connectivity

The existing natural gas pipelines offer a right-of-way for transporting green hydrogen across states. Areas located close to existing natural gas pipelines will have an advantage for transporting hydrogen. Therefore, the nexus study considers proximity to gas pipelines as an important variable to assess the readiness of hydrogen transportation infrastructure in India.

Figure A9 shows the existing and proposed natural gas pipelines in India (PNGRB 2021). The distance of a green hydrogen production node is estimated using the Euclidean distance from gas pipelines.

Figure A9 Gas pipeline network in India and Euclidean distance

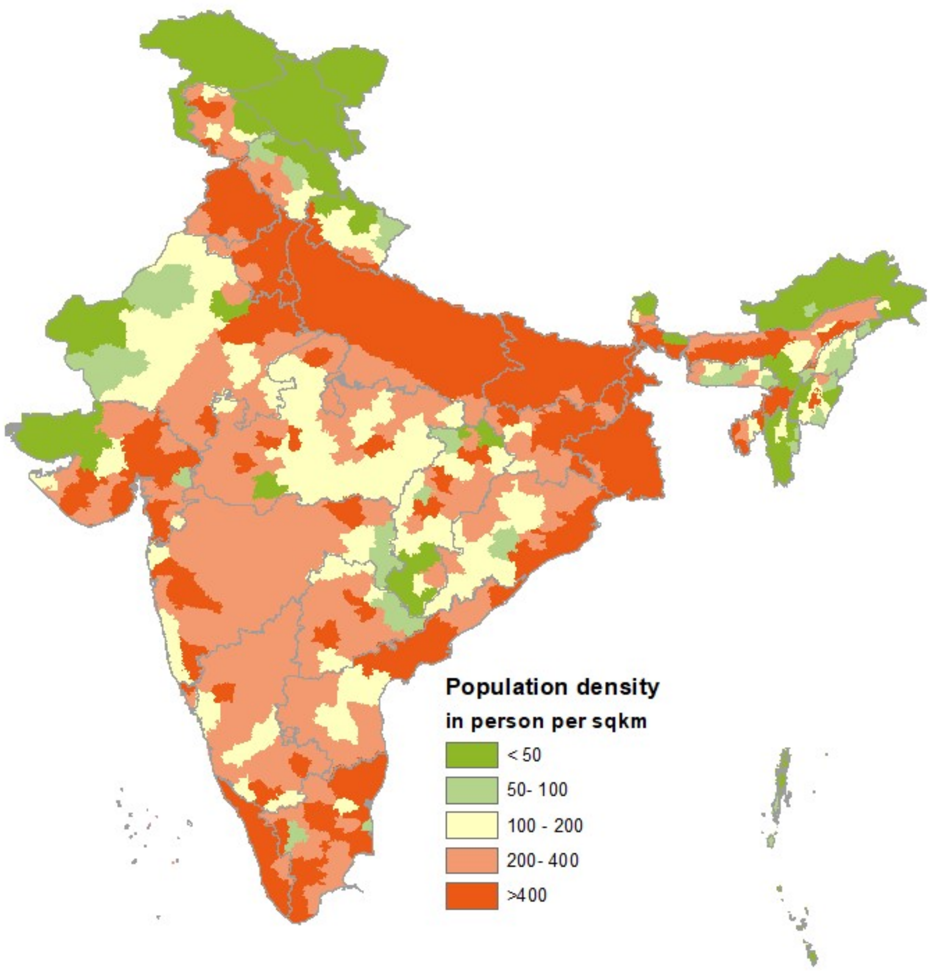


Source: PNGRB. 2021. Petroleum and Natural Gas Regulatory Board. 15 March. Accessed January 10, 2023. https://pngrb.gov.in/pdf/GAS_INFRASTRUCTURE_MOI_26102021.pdf.

e) Population density

Population density is an important variable that captures the social aspect related to RE and GH2 projects in India. Projects in areas with high population density are vulnerable to land and water conflicts as it might impact the livelihoods of people or constrain their quality of life. The information related to population density is obtained at the district level from census (MoHFW 2020). The Indo-Gangetic plane has very dense population density and it is unlikely that GH2 or RE plants will be set in these areas. Western Rajasthan and Gujarat, central Madhya Pradesh and a few pockets in South have low population density and might be amenable for setting up GH2 and RE projects.

Figure A10 District-wise population density



Source: MoHFW. 2020. Population projections for India and states 2011-2036. New Delhi: Ministry of Housing and Family Welfare.

f) Land conflicts

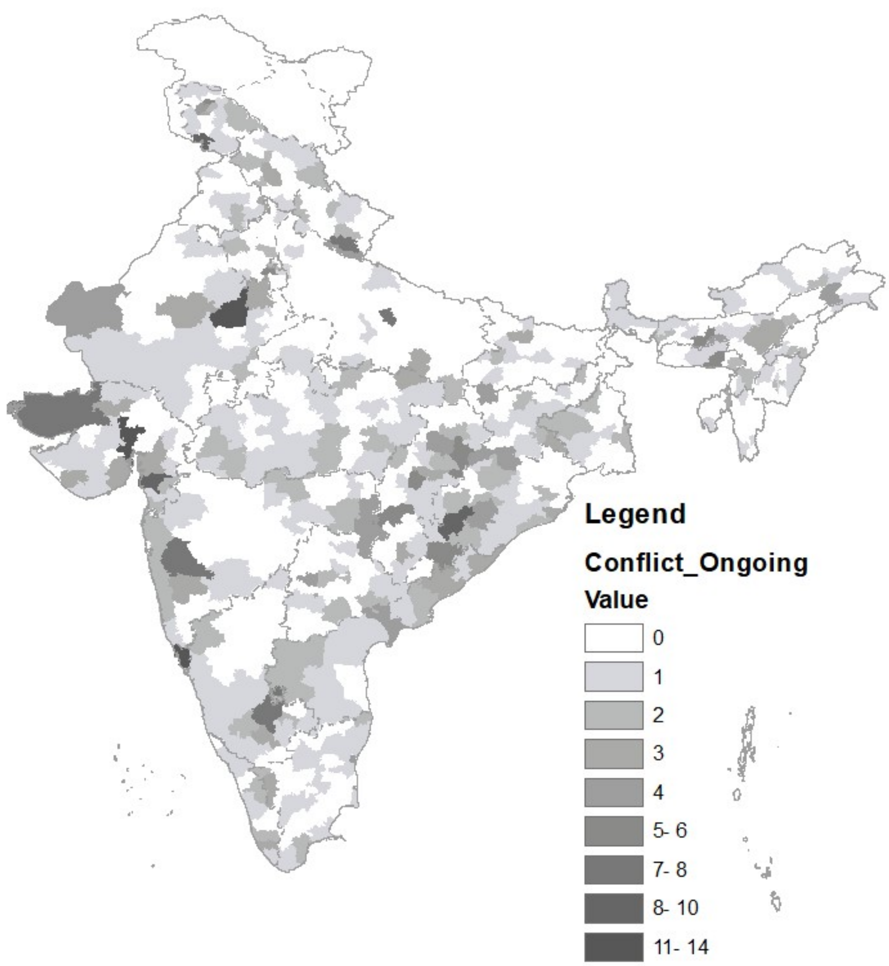
Land conflicts related to land acquisition and land use change can delay or derail the RE and GH2 projects. Therefore, land conflicts are considered as a critical parameter in the nexus study to prevent any potential conflicts. Proactive measures to address stakeholder concerns are needed in areas with past/ongoing conflicts to ensure a smooth implementation of projects. However, due to a paucity of data related to land conflicts, we face challenges in factoring in this dimension and therefore utilised the database obtained from the literature (Land Conflict Watch 2022) to highlight this aspect of the nexus study.

According to Land Conflict Watch (LCW), land conflict is defined as any instance in which the use of, access to, ownership of and/or control over land and its associated resources are contested by two or more parties, and where at least one of the contesting parties is a community (group of families). The

LCW database records only those conflicts for which documentary (and/ or audio-visual) evidence of such a contest is available for verification. Land conflicts between two private parties are excluded unless the particular conflict has a larger underlying public interest. For the nexus study, the land conflict related data is considered at a district level.

Figure A11 depicts the heat map of ongoing land conflicts across various districts in India. The values in the figure indicate the numbers of conflicts across the district. Eastern states in India have more land conflicts quite likely due to availability of mineral resources. A few RE rich areas in western Rajasthan and Gujarat have also witnessed land conflict although the land conflict watch does not attribute them to a particular project type like RE projects but mostly land use related conflicts. Most renewable energy related conflicts in the country reported in the database revolve around conflicts arising due to unfair compensation and loss of livelihood. It covers the impact of land acquisition on the community for setting up of RE plants and also the power transmission infrastructure. For example, conflicts in Rewa, Madhya Pradesh have arisen from MW Rewa Ultra Mega Solar Power Plant that have failed to generate promised employment for locals (Pandey, et al. 2023).

Figure A11 Ongoing conflicts in India

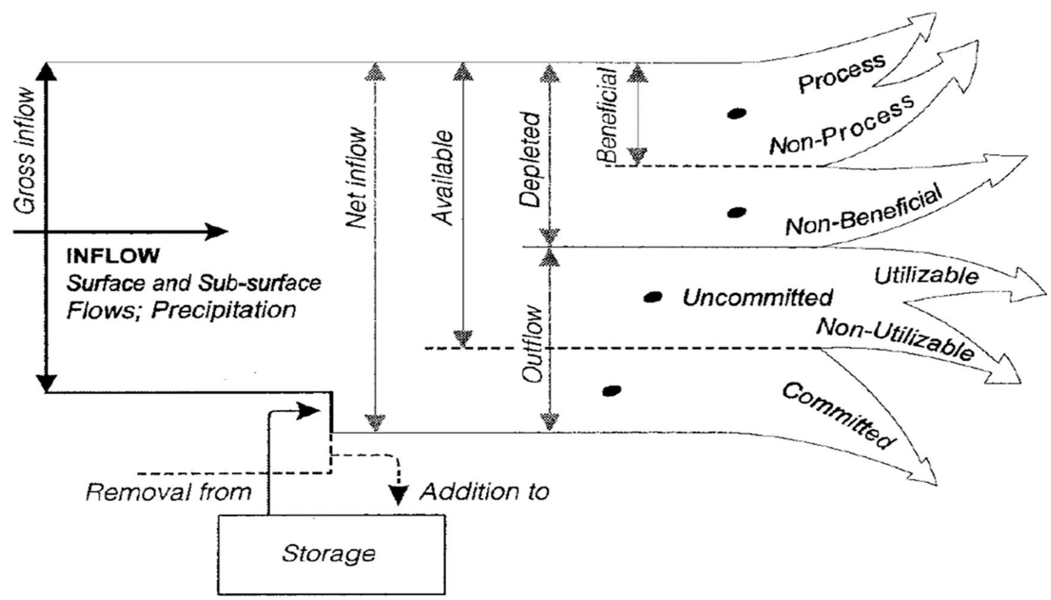


Source: "Land Conflict Watch." Land Conflict Watch. Accessed January 18, 2023. https://www.landconflictwatch.org/.

Annexure IV. Methodology for estimating district-wise internal uncommitted water

The uncommitted water can be defined as an outflow from the landscape (basin, sub-basin, or administrative unit) after meeting all demands and which is in excess of requirements for downstream uses (Figure 1). Such water is available for use within a landscape or for export to other landscapes but flows out due to a lack of storage or operational measures (Molden and Sakthivadivel 1999).

Figure A12 Schematic representing the uncommitted water in a landscape



Source: Molden, D., and R. Sakthivadivel. 1999. "Water accounting to assess use and productivity of water." International Journal of Water Resources Development 15 (1-2): pp.55-71.

For this study, district-level annual uncommitted water availability was computed using estimates of the dependable basin yield (inflow of blue water), water demand and consumptive water use across different sectors (depletion), return flow, and evaporation losses for 2019-20. For inflow, basin wise 75 per cent dependable (not the actual) annual blue water availability estimated by the Central Water Commission (CWC 2019) was considered, thus it assumed that the environmental flow requirement is met.

The various estimates prepared for computing district-level annual uncommitted water availability are discussed in the following steps:

1. **Overall blue water availability (dependable yield):** For this, (CWC 2019) estimated basin-wise annual water availability (75% dependability) was apportioned as per the area of each district falling in a particular basin. This is represented as WA_{Blue75}

2. **Water applied in agriculture (irrigation):** This has two components: groundwater and surface water. For groundwater, district-wise withdrawal for irrigation was obtained from the Central Ground Water Board (CGWB 2021). The surface water was then computed based on the proportion of groundwater and irrigated area in each district. The data on source-wise irrigated areas was obtained from the Directorate of Economics and Statistics, Government of India (Directorate of Economics and Statistics, Government of India n.d.). This is represented as $IRRI_{GW}$ and $IRRI_{SW}$ respectively.

3. **Water demands of domestic and industrial sectors**: Domestic water demand was estimated considering a supply norm of 55 lpcd for rural areas (GoI 2013) and 150 lpcd for urban areas (CPHEEO 1999). The population for 2019-20 was estimated using CAGR between the population census years 2001 and 2011. This is represented as $WD_{Domestic}$

   Industrial water demand was estimated using the (CGWB 2021) district-wise data on groundwater extraction for industrial uses and surface water allocation for thermal power plants. For the latter, the water consumption norm for the thermal power plants (3 cu m per MWh of electricity generation) was considered. This is represented as $WD_{Industry}$

4. **Consumptive water use (except livestock) and return flow:** For agriculture, the Groundwater Estimation Committee's (CGWB 2021) return flow norm for paddy and non-paddy groundwater and surface water irrigated areas were considered to determine the quantity of applied water which is consumed and that which is returned to the system (river, groundwater, or any other water body and is available for re-use). This is represented as RF_{Agri}

   The return flow from the domestic and industrial sectors is in the form of wastewater that cannot be used without treatment. Hence, they were not considered.

5. **Consumptive water use by livestock:** It was estimated using the voluntary up-take of water consumption per Livestock Unit for different types of livestock, and the Total Livestock Units (TLU) for the animal under consideration, for the prevailing climatic conditions (based on Pallas 1986). District-wise livestock data was obtained from the GoI 2019.

6. **Evaporation losses from the large reservoirs:** This was estimated considering the CWC 2006 norms for the annual evaporation rate from open surface water bodies. The area under the man-made reservoirs (pre and post-monsoon) in each state/district was accessed from the Wetland Atlas of India (Gupta, et al. 2021) and was used for estimating the evaporation losses. This is represented as $LOSS_{Evap}$

7. **Uncommitted water availability:** This is represented as WA_{UC} and estimated as:

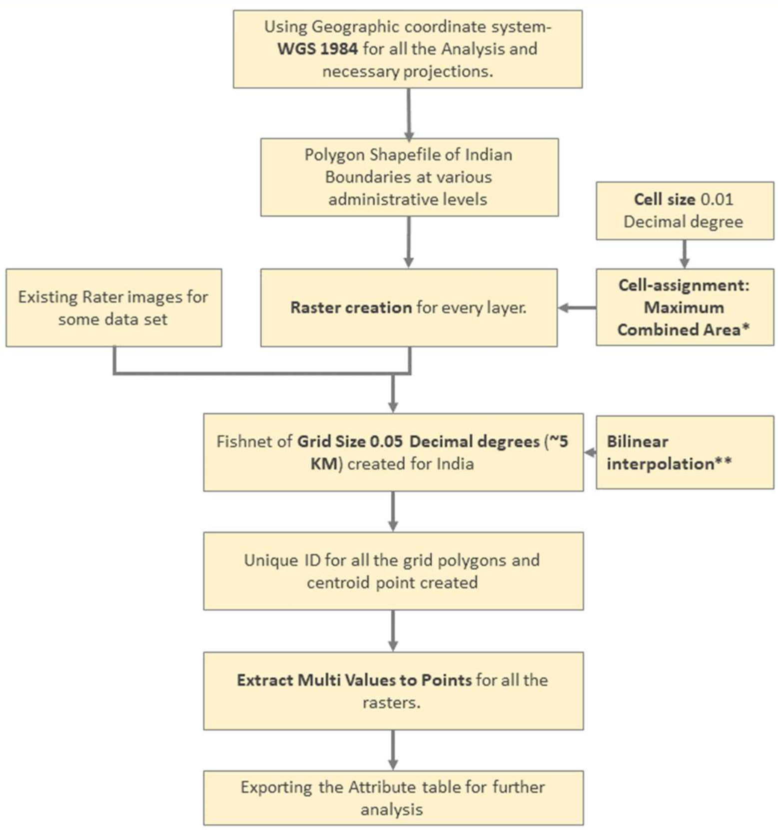
$$WA_{UC} = WA_{Blue75} - IRRI_{GW} - IRRI_{SW} - WD_{Domestic} - WD_{Industry} - WC_{Livestock} + RF_{Agri} - LOSS_{Evap}$$

Annexure V. GIS methodology

This annexure discusses in detail the method used for GIS mapping. Figure A13 provides the method used for data processing in the GIS. The datasets for all the parameters are available spatially or at an administrative unit from varied sources indicated in Annexure II. In this regard, the first step is to project all data points into a single coordinate system which is the geographic coordinate system (World Geodetic System, 1984). All numerical parameters are spatially mapped into polygons of the different administrative boundaries. Finally, all parameters are mapped into rasters that have a cell size of 0.01 decimal degrees. The raster with more available granularity are aggregated using maximum combined area such that the combined cell has the most occurring value of the smaller cells.

A grid known as fishnet is created for the entire landmass of India. Each cell is 0.05 decimal degrees (~5km) and has been allotted a unique ID. Using the tool Extract multi values to points (ArcGIS n.d.), values of raster are extracted by bilinear interpolation. This implies that the value taken for a fishnet cell is the maximum of what occurs in that cell for every raster. For example, if a particular raster shows 55 per cent built-up area, then the model considers that there is no RE (and hence GH2) potential in the given raster. However, if a neighbouring raster shows 60 per cent wasteland, then we consider that the area in the entire raster can be used for setting up RE (and hence GH2) projects. The extracted data is then further used to develop results and insights for the study.

Figure A13 Algorithm for data processing in GIS



*If there is more than one feature in a cell with the same value, the areas of these features will be combined. The combined feature with the largest area within the cell will determine the value to assign to the cell.
** The value of the cell will be calculated from the adjacent cells with valid values using bilinear interpolation.

Source: Authors' analysis

Annexure VI. GIS Sensitivity analysis

In the base case, the study considers a raster size of 5 km xx 5 km to estimate the RE and GH2 production potential in the country. The raster size is chosen to reduce the computational load for estimating the production potential, LCOE and LCOH. However, the raster size for the assessment can also be reduced to provide more granular information. Table A3 shows the comparison of solar potential in the country for a 5 km * 5 km raster size and a 100 m*100 m raster size. While there is a significant variation in the solar potential loss due to No-go zones, areas with water reserves and areas with slope exceeding 20 per cent, there is no significant difference between the unconstrained and net solar potential. There is a variation of only 0.1 per cent for the net solar potential in the country for a raster size of 5 km * 5 km compared to a more granular 100 m * 100 m resolution.

Table A3 Net solar potential varies only by 0.1 per cent for a more granular raster size

Sr. No.	Parameters	Solar potential (GW) at 5 km detail	Solar potential (GW) at 100 m detail	Relative change (per cent)
1	Unconstrained	145591	142253.5	-2%
2	Potential loss in NoGo areas	11587	8616.1	-26%
3	Potential loss in areas with water reserves	6469	4525.5	-30%
4	Potential loss in built-up areas	8660	8522.7	-2%
5	Potential loss in trees	21724	22293.7	3%
6	Potential loss in cropland	66356	67367	2%
7	Potential loss in areas with slope > 20 percent	1123	1279	14%
8	**Net solar potential**	**29672**	**29649.6**	**-0.1%**

Source: Authors' analysis

Annexure VII. State wise RE Potential

This section of the annexure lists the unconstrained and the realisable wind and solar potential across various states in India.

Wind Potential

Table A4 lists the wind potential along with the various constraints across all states in India. The wind potential is indicated for a PLF higher than 30 per cent. We consider a land requirement of 9 MW per sq.km. for wind power projects.

Table A4 Wind potential is concentrated in southern and western states

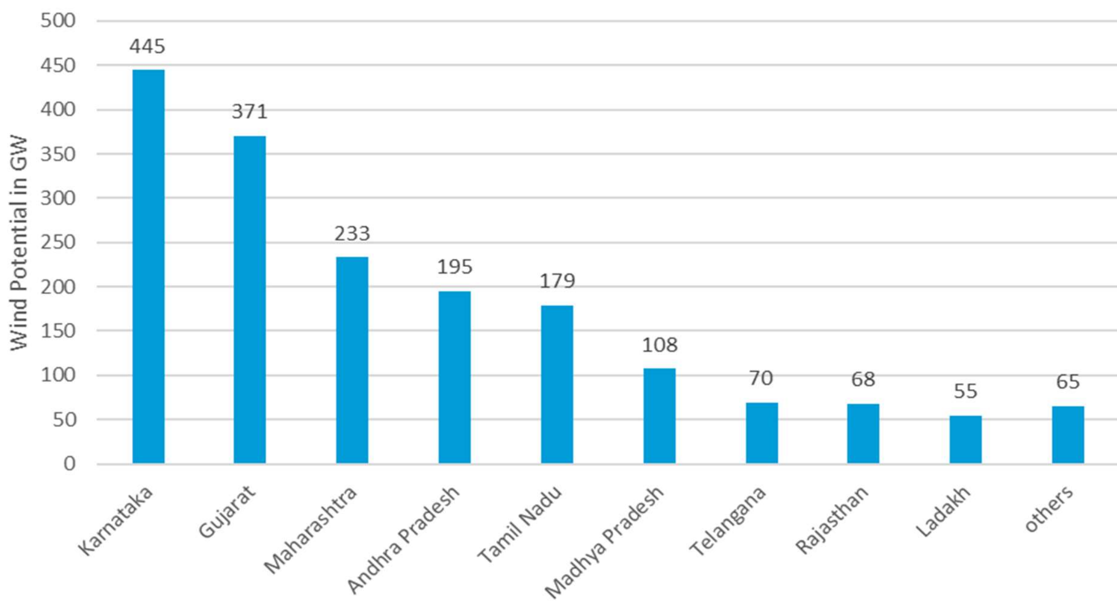
States	Total unconstraint Wind Potential	Potential excluded due to NOGO zones and area not under Indian control	Potential excluded due to LULC constraints	Potential excluded due to Slopes >20% and PLF < 30%	Net Potential
Andaman & Nicobar Island	12.2	2.7	8.8	0.2	0.5
Andhra Pradesh	562.7	36.2	96.8	234.5	195.3
Arunachal Pradesh	11.7	0.5	6.1	2.0	3.2
Assam	1.4	0.0	1.4	0.0	0.0
Bihar	3.8	1.1	0.5	2.3	0.0
Chandigarh	0.0	0.0	0.0	0.0	0.0
Chhattisgarh	20.7	1.4	9.9	9.2	0.2
Dadra and Nagar Haveli	1.4	0.0	0.9	0.5	0.0
Daman & Diu	0.9	0.2	0.5	0.2	0.0
Goa	0.9	0.9	0.0	0.0	0.0
Gujarat	973.8	104.6	121.3	377.3	370.6
Haryana	1.6	0.0	0.0	1.6	0.0
Himachal Pradesh	75.2	18.5	21.8	14.2	20.7
Jammu Kashmir	36.9	2.5	17.8	7.4	9.2
Jharkhand	2.7	0.0	1.6	1.1	0.0
Karnataka	980.1	27.9	164.3	342.7	445.3
Kerala	51.5	11.0	31.7	2.0	6.8

Ladakh	268.4	166.1	17.1	30.4	54.9
Lakshadweep	0.5	0.0	0.5	0.0	0.0
Madhya Pradesh	383.2	5.2	26.6	243.5	108.0
Maharashtra	741.4	18.9	72.9	416.3	233.3
Manipur	6.1	0.2	3.2	1.6	1.1
Meghalaya	1.8	0.0	1.8	0.0	0.0
Mizoram	1.8	0.5	1.1	0.2	0.0
Nagaland	0.0	0.0	0.0	0.0	0.0
NCT of Delhi	0.0	0.0	0.0	0.0	0.0
Odisha	117.2	7.7	49.7	43.9	16.0
Puducherry	3.2	0.0	1.6	1.1	0.5
Punjab	0.2	0.0	0.0	0.2	0.0
Rajasthan	476.1	25.4	98.3	284.2	68.2
Sikkim	6.5	2.9	0.9	0.9	1.8
Tamil Nadu	445.1	30.6	116.8	118.4	179.3
Telangana	269.3	14.0	34.4	151.4	69.5
Tripura	0.7	0.0	0.7	0.0	0.0
Uttar Pradesh	1.6	0.0	0.5	1.1	0.0
Uttarakhand	28.8	10.8	11.9	2.9	3.2
West Bengal	29.3	0.5	14.4	13.1	1.4
Grand Total	**5546.0**	**493.7**	**958.1**	**2304.5**	**1789.9**

Source: Authors' analysis

Figure A14 shows the distribution of net realisable wind potential across various states in India. Karnataka, Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu have the highest wind potential.

Figure A14 Southern and western states in India have the highest wind potential



Source: Authors' analysis

Solar potential

Table A5 lists the solar potential along with the various constraints across all states in India. The data shows that a significant share of solar potential across all states is lost due to crop lands. The total solar potential in the country is 25492 GW**.** We assume a land intensity of 49 MW per sq.km. for solar power plants.

Table A5 Significant share of solar potential is lost due to cropland

States	Total unconstraint Solar Potential	Potential excluded due to NOGO zones and area not under Indian control	Potential excluded due to LULC constraints	Potential excluded due to Slopes >20%	Net Potential
Andaman & Nicobar Island	304	28	268	0	7
Andhra Pradesh	6611	354	4849	0	1409
Arunachal Pradesh	3688	470	2886	39	293
Assam	3467	212	2991	0	263
Bihar	4145	176	3762	0	207

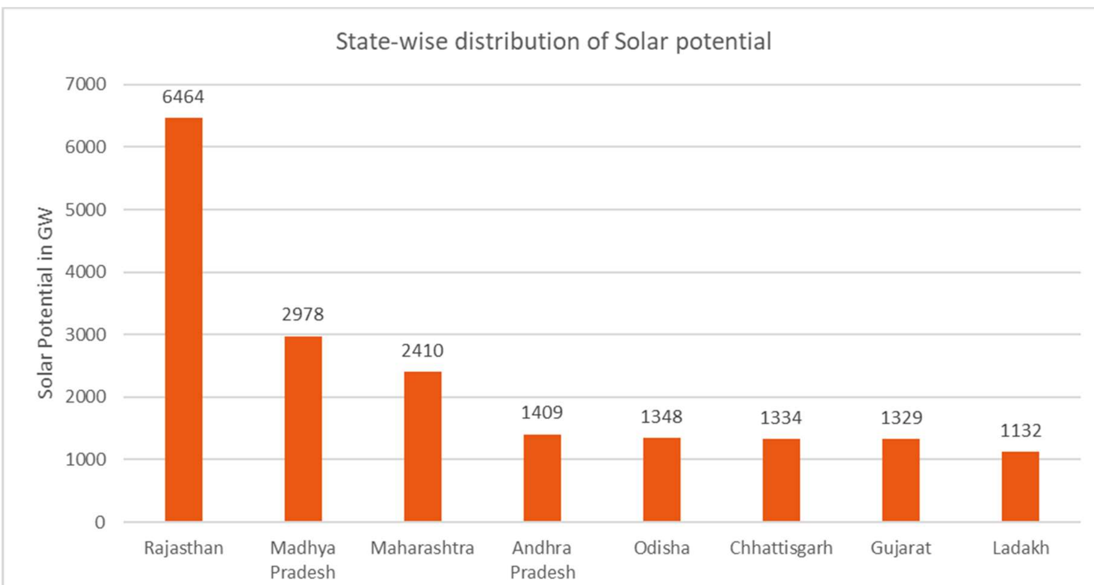
Chandigarh	5	0	5	0	0
Chhattisgarh	5756	347	4076	0	1334
Dadra and Nagar Haveli	18	0	15	0	4
Daman & Diu	5	1	4	0	0
Goa	151	33	97	0	21
Gujarat	8004	660	6015	0	1329
Haryana	2008	10	1950	0	48
Himachal Pradesh	2602	387	1106	157	952
Jammu Kashmir	2532	604	1193	77	658
Jharkhand	3475	99	2724	0	652
Karnataka	7873	412	6595	0	866
Kerala	1573	121	1392	0	60
Ladakh	8179	6769	212	66	1132
Lakshadweep	16	7	9	0	0
Madhya Pradesh	13361	463	9920	0	2978
Maharashtra	12984	412	10163	0	2410
Manipur	978	34	824	0	119
Meghalaya	992	23	831	0	138
Mizoram	910	55	800	0	55
Nagaland	734	17	676	0	40
NCT of Delhi	69	0	66	0	2
Odisha	6619	314	4958	0	1348
Puducherry	20	0	20	0	0
Punjab	2323	7	2294	0	21
Rajasthan	15184	475	8244	0	6464
Sikkim	317	93	145	5	75
Tamil Nadu	5264	304	4438	0	522

Telangana	4787	296	3780	0	711
Tripura	453	31	420	0	2
Uttar Pradesh	10741	272	9932	0	537
Uttarakhand	2460	399	1291	88	681
West Bengal	3695	160	3404	0	130
Grand Total	**145591**	**17088**	**102579**	**432**	**25492**

Source: Authors' analysis

Figure A15 shows the solar potential across various states in India. Rajasthan has the highest solar potential followed by Madhya Pradesh, Maharashtra and Andhra Pradesh. Odisha has higher potential than Gujarat although the cost of generation in Odisha is higher than Gujarat due to high land prices and low solar availability.

Figure A15 Rajasthan has significantly higher solar potential than other states



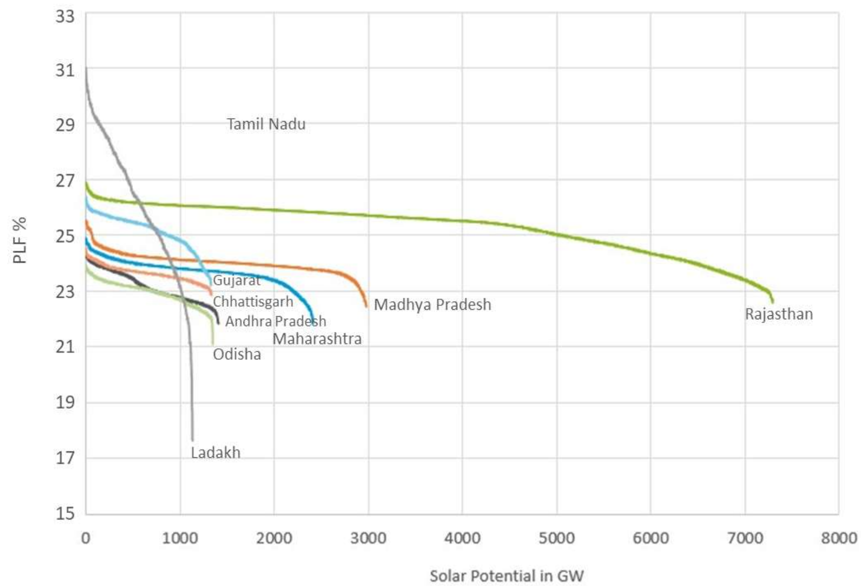
Source: Authors' analysis

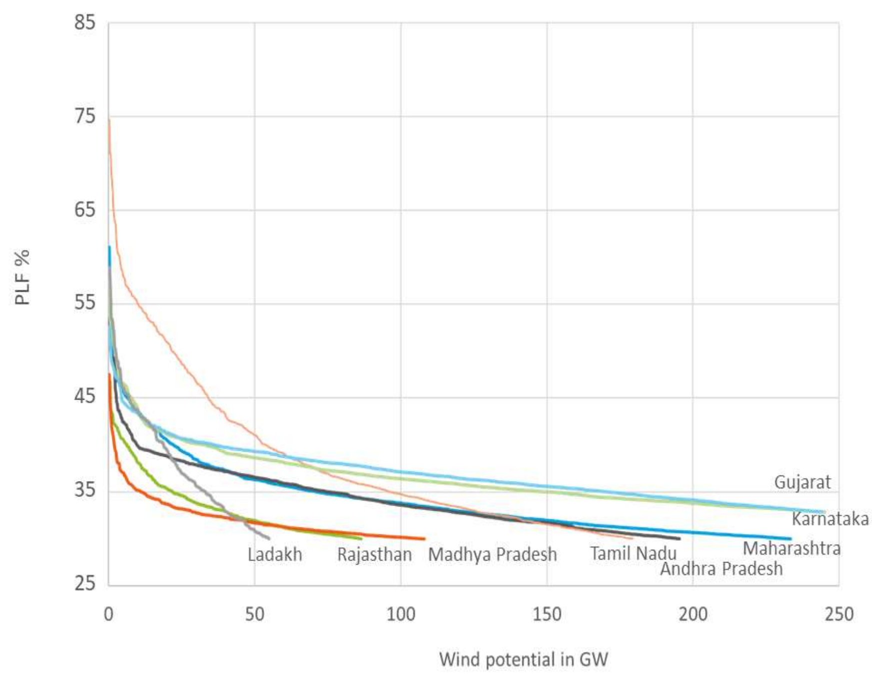
Variation in solar and wind PLF across states in India

Figure A16 shows a plot of variation in solar PLF with potential across major solar states in India. The PLF is indicated for 30 per cent oversizing on the DC side. Rajasthan has the highest potential and also good solar PLF across the entire capacity. Although a few areas in Ladakh have very good solar PLF, there is a sharp decrease in PLF as higher capacity gets unlocked. Rajasthan has the highest solar PLF and also the largest solar potential. Although Madhya Pradesh has higher solar potential, Gujarat has better quality solar resource in terms of PLF. Similarly, Odisha and Gujarat have the same solar potential but Gujarat has a significantly better solar resource.

Although Tamil Nadu has the best wind PLF in India, the wind availability significantly reduces to below that in Gujarat and Karnataka beyond a capacity of 60 GW. Gujarat and Karnataka have similar wind potential and the resource quality without accounting for seasonal variation. Although Maharashtra has wind potential similar to Gujarat and Karnataka, the wind PLF is comparatively lower. Rajasthan and Madhya Pradesh has limited potential with PLFs exceeding 35 per cent.

Figure A16 Rajasthan has best solar PLF and largest potential; Tamil Nadu has the best wind profile although potential is comparatively lower than other states



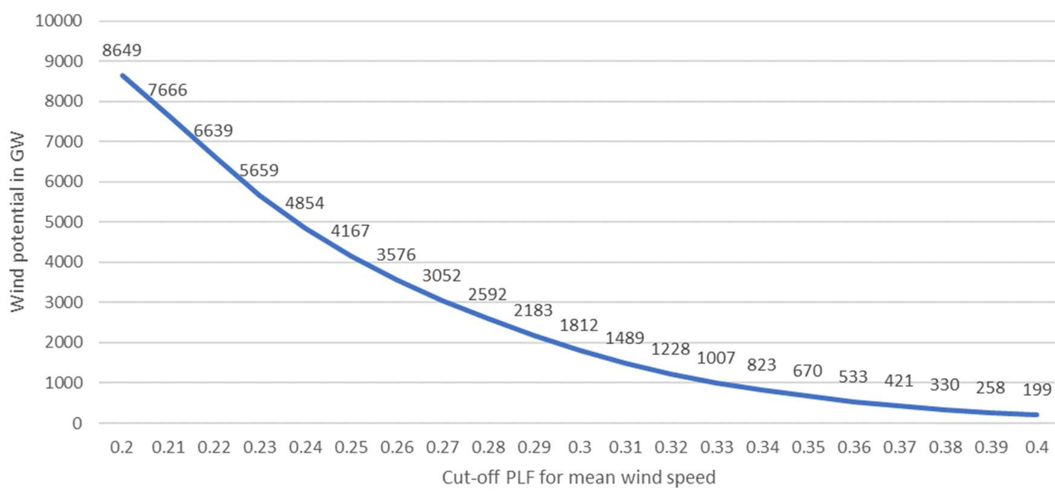


Source: Authors' analysis

Annexure VIII. Sensitivity analysis for wind and solar potential and cut-off PLF

The wind potential is a strong function of the PLF cut-off and hub height. Figure A17 shows that India has a wind potential exceeding 8500 GW for a cut-off PLF of 20 per cent. However, the potential decreases steeply to 4000 GW for a PLF cut-off of 25 per cent and to 1800 GW for a 30 per cent PLF cut-off. Therefore, although India has significant wind potential, the cost of generation is expected to increase significantly as India start unlocking potential in low PLF areas. The wind potential in Figure 17a is indicated for a hub height of 100 m.

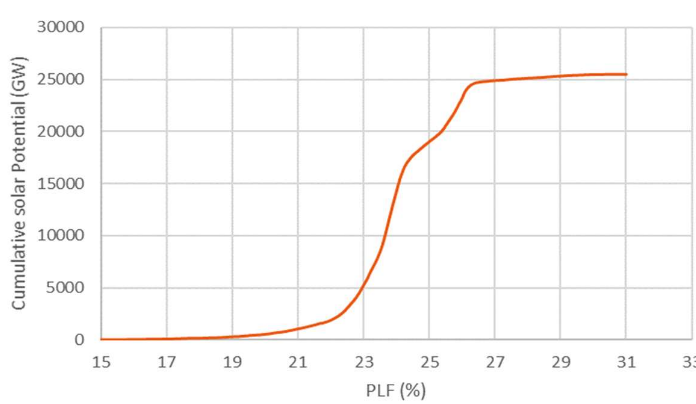
Figure A17a Wind potential decreases steeply with an increase in PLF cut-off



Source: Authors' analysis

Figure A17b shows the solar potential as a function of cut-off PLF. It can be seen that, unlike wind potential, the solar potential follows a classic S-curve. This is because there is no significant variation in solar PLF across the country. We select a cut-off PLF of 23 per cent as there is only a marginal decrease in solar potential beyond this point.

Figure A17b Solar potential as a function of cut-off PLF



Source: Authors' analysis

Annexure IX. Sensitivity analysis for land requirement factors

There is an uncertainty in land requirement for RE power projects. Based on literature and industry inputs, we consider the two extremities of land required for wind and solar projects and estimate the corresponding potential in India. Our analysis indicates that the wind potential in India could vary from 1000 GW to 2600 GW depending on the land requirements. Similarly, the solar potential can increase to ~50000 GW, if the land requirement reduces significantly. The base-case assumptions and the corresponding RE potential are indicated in green.

Table A6 Sensitivity of wind and solar potential in India

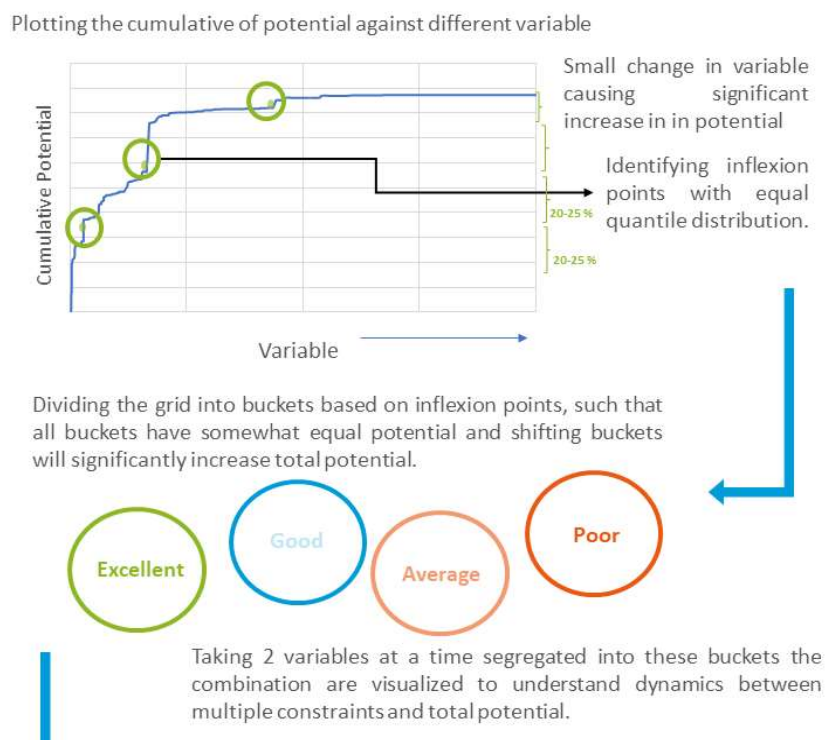
RE type		Potential (GW)
Wind	9 MW per square km (base case)	1808.4
	5 MW per square km	1006.9
	13 MW per square km	2617.9
Solar	49 MW per square km (base case)	29926.9
	82 MW per square km	49878.1

Source: Authors' analysis

Annexure X. How to read the bubble chart?

Figure A18 illustrates the method considered for identifying inflection point and bucketing parameters across the data range. The inflection points correspond to data where a small change in variable results in significant increase in the potential. The data between the inflection points is bucketed together to provide insights.

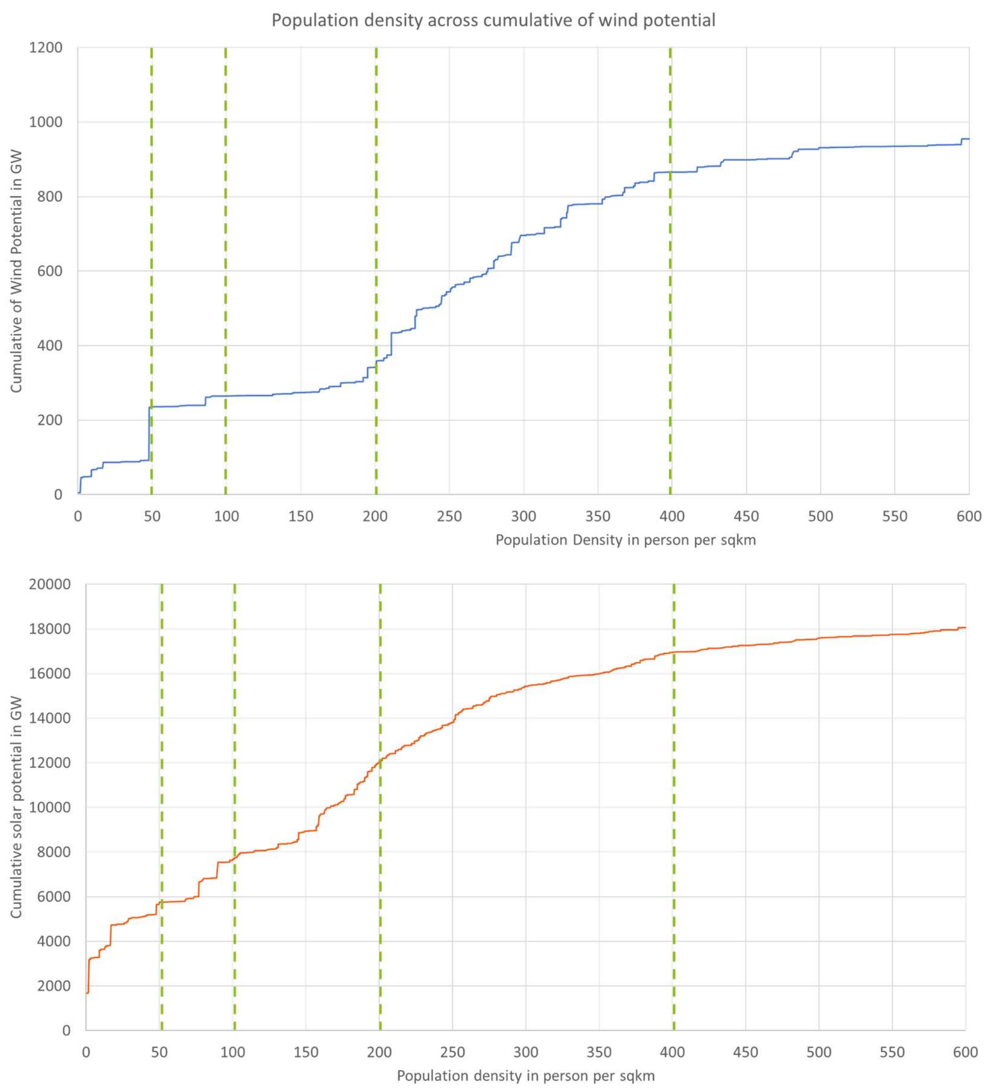
Figure A18 Identifying inflection points and data bucketing provides research insights



Source: Authors' analysis

When population density is plotted against cumulative of wind and solar potential respectively, we can see high increase in RE potential with small change in population density at some points which we use as inflexion points to divide potential in population density buckets.

Figure A19 The inflexion points for population density are 50, 100, 200, 400 persons per sq km



Source: Authors' analysis

Annexure XI. Methodology for calculating land lease rate

The circle rate of land is obtained from various state government portals. Table A7 lists the states and the provides a link to the corresponding webpage from which circle rates are obtained.

Table A7 State-wise land prices websites

Sr. No.	State	Website
1	Andaman and Nicobar Island	https://www.andaman.gov.in/admin-pannel/pressupload/1-17-circle%20rates.pdf
2	Andhra Pradesh	http://rs.ap.gov.in/UnitRateMV.do?method=getDistrictList&uType=U
3	Arunachal Pradesh	https://www.land.arunachal.gov.in/circular
4	Assam	https://dlrar.assam.gov.in/sites/default/files/Market%20value%20of%20Land.pdf
5	Bihar	http://bhumijankari.bihar.gov.in/Admin/MVR/MVRView.aspx
6	Chandigarh	https://chandigarh.gov.in/sites/default/files/documents/dc-cr2017.pdf
7	Chhattisgarh	cgstate.gov.in
8	Daman	https://daman.nic.in/websites/Civil-Registrar/2020/11-14-01-2020.pdf
9	Delhi	https://housing.com/news/new-delhi-circle-rate/
10	Goa	https://tcp.goa.gov.in/wp-content/uploads/2021/04/Sr-I-No-1-2021-2022-2122-01-SI-OG-0.pdf
11	Gujarat	https://garvi.gujarat.gov.in/WebForm1.aspx
12	Haryana	https://jamabandi.nic.in/HARIS/Collector1New
13	Himachal Pradesh	https://ngdrshp.gov.in/NGDRS_HP_LIVE/MISReports/rpt_public circlerates
14	Jammu & Kashmir	https://cdn.s3waas.gov.in/s3f4b9ec30ad9f68f89b29639786cb62ef/uploads/2021/12/2021123137.pdf
15	Jharkhand	http://regd.jharkhand.gov.in/jars/website/frmNewVaDownload.aspx
16	Karnataka	Karnataka Guideline Value, Property Market Value in Karnataka (localitydetails.com)
17	Kerala	FAIR VALUE OF LAND (kerala.gov.in)
18	Lakshwadeep	https://lakshadweep.gov.in/service/land-register-extract/
20	Madhya Pradesh	https://www.mpigr.gov.in/#/guidline-view
21	Maharashtra	eASR Rates (igrmaharashtra.gov.in)
22	Mizoram	https://landrevenue.mizoram.gov.in/uploads/attachments/eb5a2a3d00b9955dadf68536c7740abe/pages-35-land-lease-rate-thar.pdf
23	Nagaland	https://www.99acres.com/residential-land-in-nagaland-ffid

24	Odisha	Benchmark Valuation (igrodisha.gov.in)
25	Punjab	Collector Rate in Punjab | Official Website of Department Revenue,Rehabilitation and Disaster Management, Government of Punjab,India
26	Rajasthan	DLC Rates | Registration & Stamps Department, Rajasthan
27	Sikkim	http://www.sikkimlrdm.gov.in/Notifications/Block%20Rate%20Sikkim%20may%202018.pdf
28	Tamil Nadu	https://tnreginet.gov.in/portal/webHP?requestType=ApplicationRH&actionVal=homePage&screenId=114&UserLocaleID=en&_csrf=ed8ff27b-df22-42be-9814-eebf15adc295
29	Telangana	View market value of lands for Stamp Duty (telangana.gov.in)
30	Tripura	https://industries.tripura.gov.in/allotment-rates
31	Uttar Pradesh	https://igrsup.gov.in/igrsup/getUploadedRateList
32	Uttarakhand	https://registration.uk.gov.in/details/view/2

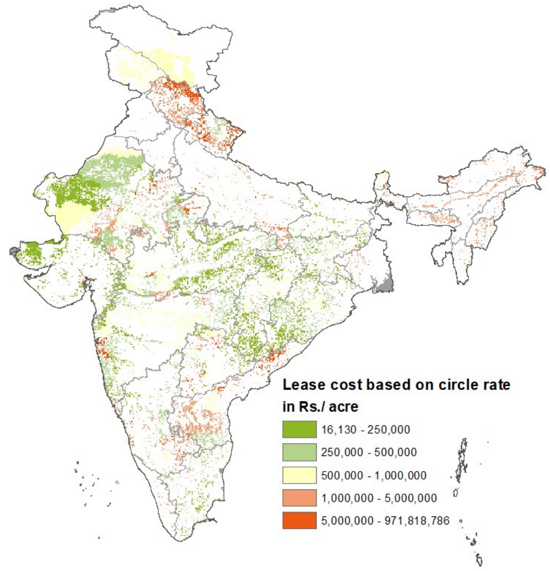
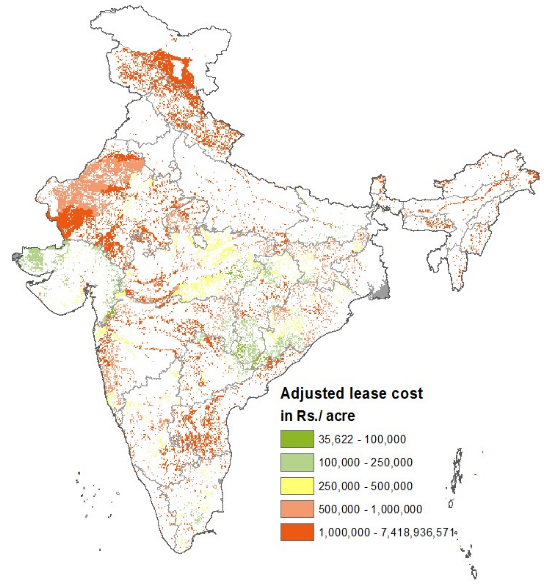
Source: Authors' compilation

The LCOE for RE and LCOH for green hydrogen rely significantly on the price of land amongst other variables like RE PLF. There is no single database or source to derive land prices across the country. Each state has a portal that provides the circle rates at a district level; some easier to access than others. However, circle rates based on a few spot checks were found to be too low compared to generally known market prices. Further, there is no source of data for market prices of land across the country. Hence, we used the circle rates at a raster and adjusted it to directly reflect potential lease cost as follows.

We determined the circle rates from state websites for all the land parcels where there are existing solar parks. These circle rates were converted into land lease costs assuming that the lease cost is 3 per cent (No Broker 2021) of the price of land. Subsequently, we determined the median lease cost for all existing solar parks, which is INR 16,980 per acre. We know from our previous analysis that the average lease cost paid by developers is INR 37,500 per acre. The ratio of this known developer lease cost (INR 37,300 per acre) and the median lease cost (INR 16,980 per acre) is 2.21. We separately estimated similar ratios for each state. Any state that had a ratio of less than 2.21 was assigned a ratio of 2.21. Any state with ratio higher than 2.21 was retained as is.

Figure A20 shows the circle rates of land (on the left) and the final land cost (on the right) considered in the assessment. For the assessment, we consider that the land lease cost is 3 per cent of the land cost indicated in the circle rate provided by various state government portals (No Broker 2021). It can be seen that the adjusted lease cost are significantly higher than the circle rates especially for areas in Rajasthan that have good solar potential. Further, the land prices in Odisha, Maharashtra and Andhra Pradesh also increase compared to cricle rates. The analysis can be further refined, if more accurate data related to market price of land is available.

Figure A20 Circle and market rates of land considered for RE installation

Circle rates	Market rates
	

Source: Authors' analysis

Table A8 lists the state-specific circle rate multiplier and final multiplier factor selected for estimating the land price.

Table A8: Circle rate multiplier across various states in India

Sr. No.	State	Circle rate multiplier (from data)	Final multiplier	Solar capacity (MW)
1	Punjab	2.00	2.00	801
2	Madhya Pradesh	0.45	2.21	2150
3	Maharashtra	0.37	2.21	1461
4	Telangana	2.60	2.60	3368
5	Tamil Nadu	0.20	2.21	3209
6	Kerala	2.16	2.16	79
7	Uttar Pradesh	0.91	2.21	937
8	Andhra Pradesh	3.55	3.55	3410
9	Karnataka	1.23	1.23	6372
10	Rajasthan	3.14	3.14	4657
11	Gujarat	0.18	2.21	2175
12	Uttarakhand	55.57	55.57	167
13	Chhattisgarh	0.86	2.21	164
14	Odisha	0.26	2.21	383
15	West Bengal	2.70	2.70	67
16	Assam	0.80	2.21	5
17	Bihar	0.06	2.21	103
18	Andaman and Nicobar	3.85	3.85	25
19	Haryana	4.31	4.31	92

Source: Authors' analysis

Annexure XII. Assumptions for calculating LCOE of wind and solar power

Tables A9 and A10 lists the major assumptions related to capital and operating cost of solar and wind power plants, respectively.

Table A9 Assumptions for techno-economic analysis of solar systems

Sr. No.	Component	Units	Value	Reference
		Solar capex cost		
1	Cost of solar module	cents/W-dc	27.5	(Dutt, et al. 2021)
2	DC oversizing	per cent	30	-assumption-
3	Solar BoP cost	USD/kW	120	(Dutt, et al. 2021)
4	One time solar park cost	USD/kW	64	(Dutt, et al. 2021)
5	Degradation cost	USD/kW	13	(CERC 2016)
6	Solar system cost	USD/kW	555	-
		Solar O&M costs		
7	Insurance cost	percent of total capex	0.5	(Hay 2016)
8	Solar park charges	percent of total capex	0.8	(Dutt, et al. 2021)
9	Other O&M charges	percent of total capex	0.9	(Dutt, et al. 2021)
10	Total O&M charges	percent of total capex	2.2	-
		Land-related and miscellaneous parameters for solar project		
11	Land intensity of solar plants	MW-ac/sq.km	49	(Dutt, et al. 2021)
12	Land rent as per cent of capital cost	per cent	3	(No Broker 2021)
13	Annual escalation in land rent charges	per cent	5	(Dutt, et al. 2021)
14	Life of solar PV plant	years	25	(Dutt, et al. 2021)

Source: Authors' compilation

Table A10 Assumptions for techno-economic analysis of wind systems

Sr. No.	Component	Units	Value	Reference
		Wind capex cost		
1	Cost of wind power plants (including degradation cost)	USD/kW	900	(Dutt, et al. 2021)
		Wind O&M costs		
2	Insurance cost	percent of total capex	0.5	(Hay 2016)
3	Other O&M cost	percent of total capex	1.5	(Dutt, et al. 2021)
4	Total O&M cost	percent of total capex	2	(Dutt, et al. 2021)
		Land-related and miscellaneous parameters for wind project		
5	Land intensity of solar plants	Acre/MW	1.8	(Dutt, et al. 2021)
6	Land rent as per cent of capital cost	per cent	3	(*PP to provide*)
7	Annual escalation in land rent charges	per cent	5	
8	Life of solar wind plant	years	25	(Dutt, et al. 2021)

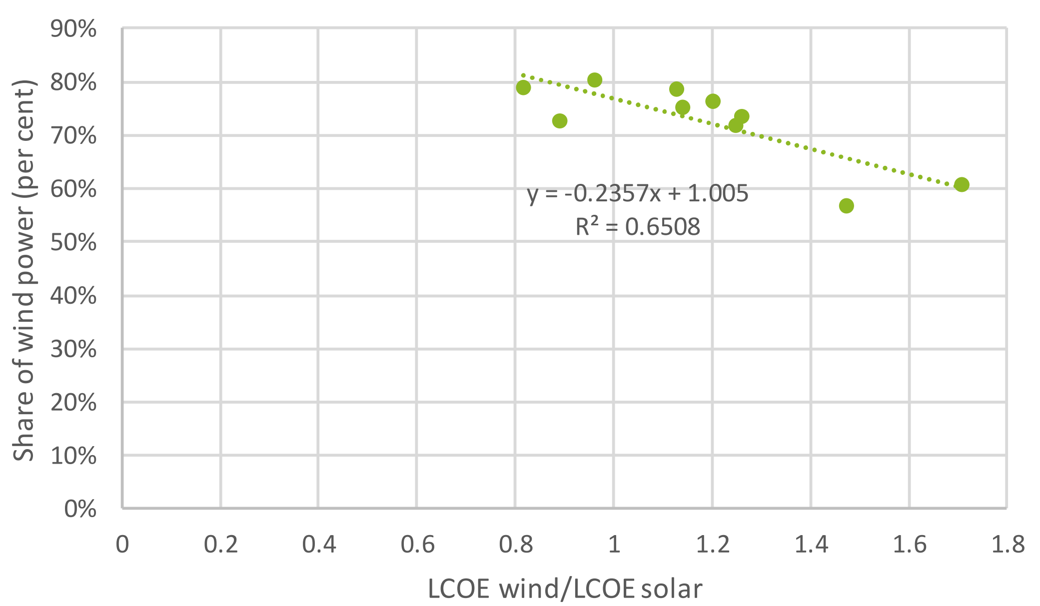
Source: Authors' compilation

Annexure XIII. Assumption for calculating LCOH

The cost of green hydrogen in the study considers up to 85 per cent availability of hydrogen on an annual basis. This consideration removes any computational complexity associated with the seasonality of RE. Consequently, the cost of green hydrogen becomes a strong function of LCOE and electrolyser costs. This section of the annexure discusses the methodology followed for estimating green hydrogen costs across various locations considered in the study. A detailed methodology is illustrated for the wind-solar hybrid (WSH) configuration below.

For a WSH configuration, the split between the use of solar and wind power for producing green hydrogen depends on the relative cost of the RE power. Figure A21 shows the share of wind power as a function of LCOE wind/LCOE solar for a few cases obtained from the model runs (Biswas, Yadav and Guhan 2020). It is seen that for the same cost of solar and wind power (ratio being 1), the share of wind power in total power consumption is around 77 per cent. This share decreases with an increase in the cost of wind power. The LCOEs of wind and solar power are obtained by using the assumptions discussed in Annexure XII.

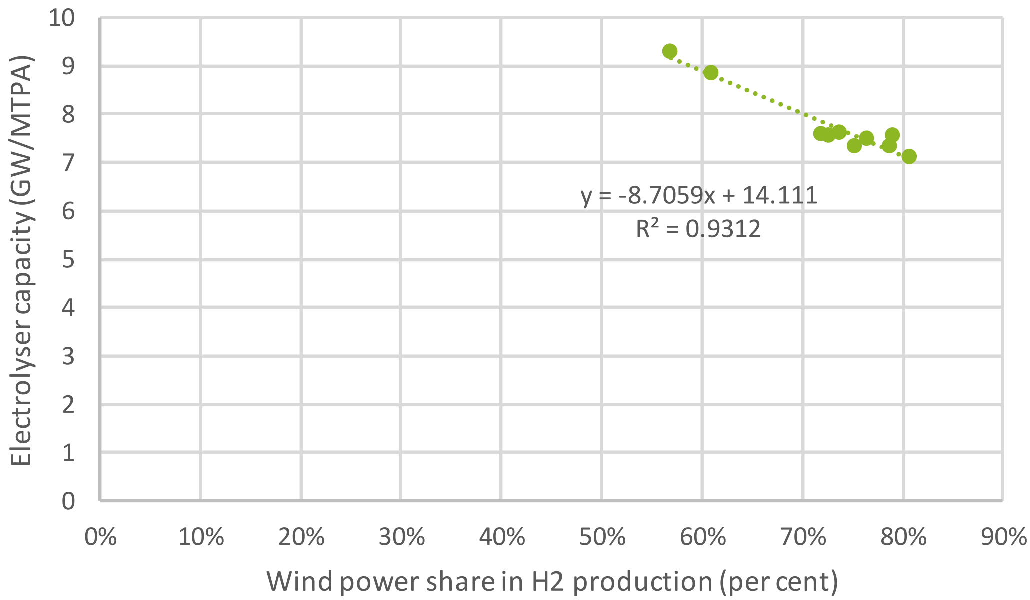
Figure A21 Share of wind power depends on the cost of generation



Source: Authors' analysis

Compared to solar energy, wind power is available for a higher number of hours annually. Therefore, it is expected that the electrolyser will have a higher PLF and consequently lower capacity requirement for a higher share of wind power. Figure A22 shows a plot of electrolyser capacity requirement as a function of wind power share in H2 production. It is seen that the electrolyser capacity requirement reduces linearly with an increase in wind power share. As shown in Figure A21, the share of wind power in a green hydrogen plant depends on the relative LCOE of wind and solar power plant. Therefore, it is expected that the electrolyser capacity requirement will be lower in areas having higher wind PLFs.

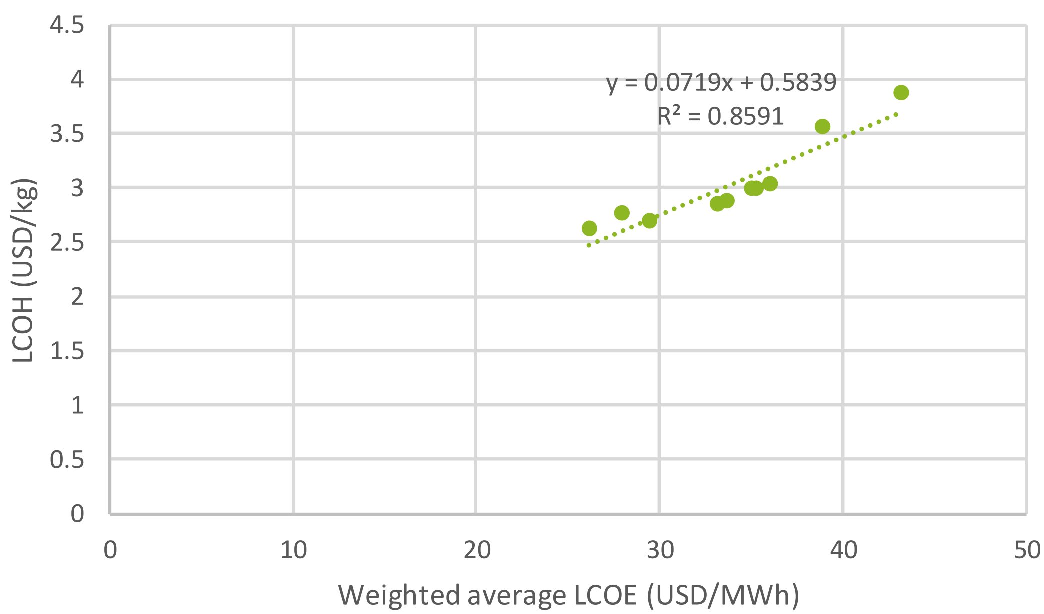
Figure A22 Electrolyser capacity deployment depends on the share of wind power



Source: Authors' analysis

Figure A23 shows a plot of green hydrogen production cost as a function of weighted average cost of LCOE obtained by using wind and solar power. It is seen that the hydrogen production cost is very strongly linked with the cost of power generation.

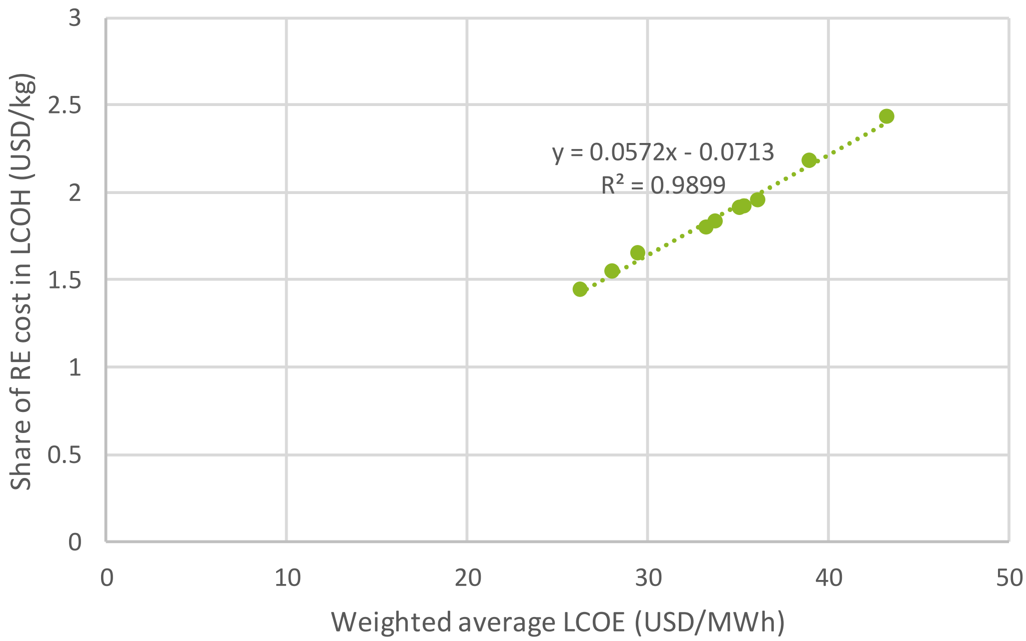
Figure A23 Green hydrogen production cost is a strong function of LCOE



Source: Authors' analysis

The share of RE in the overall green hydrogen cost depends on the LCOE. A lower LCOE indicates lower cost of power generation and consequently lower cost of green hydrogen. The split between cost attributable to solar and wind power is obtained based on the respective share indicated in Figure A21.

Figure A24 Share of RE in LCOH depends on the cost of generation

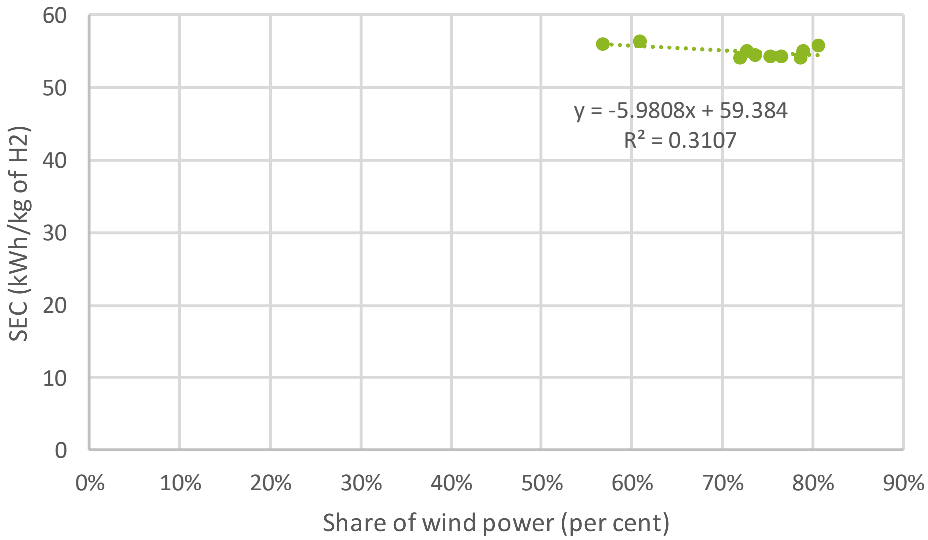


Source: Authors' analysis

The annual green hydrogen output is obtained from the RE potential in a raster, the RE PLF and the specific energy consumption (SEC) for hydrogen production. The RE potential is obtained from the methodology discussed in section 3-5 of the main manuscript and the RE PLF is obtained from global solar (Global Solar Atlas 2023) and wind (Global Wind Atlas 2023). The SEC of green hydrogen includes the energy used by electrolyser and the surplus power. While the power consumption in the electrolyser is a fixed value of 50.5 kWh per kg of H2 output, the surplus power depends on the share of wind and solar power at a particular raster.

Figure A25 shows the trend of variation in SEC of the electrolyser with the wind power share. It is seen that SEC reduces with an increase in wind share due to lower curtailment associated with wind power. While the regression analysis indicates a weak correlation of SEC with wind power share, generally the SEC ranges between 54-56 kWh per kg of H2 output. This implies that the surplus power is around 8 – 12 per cent of the annual generation.

Figure A25 SEC (including surplus power) depends on the share of wind power

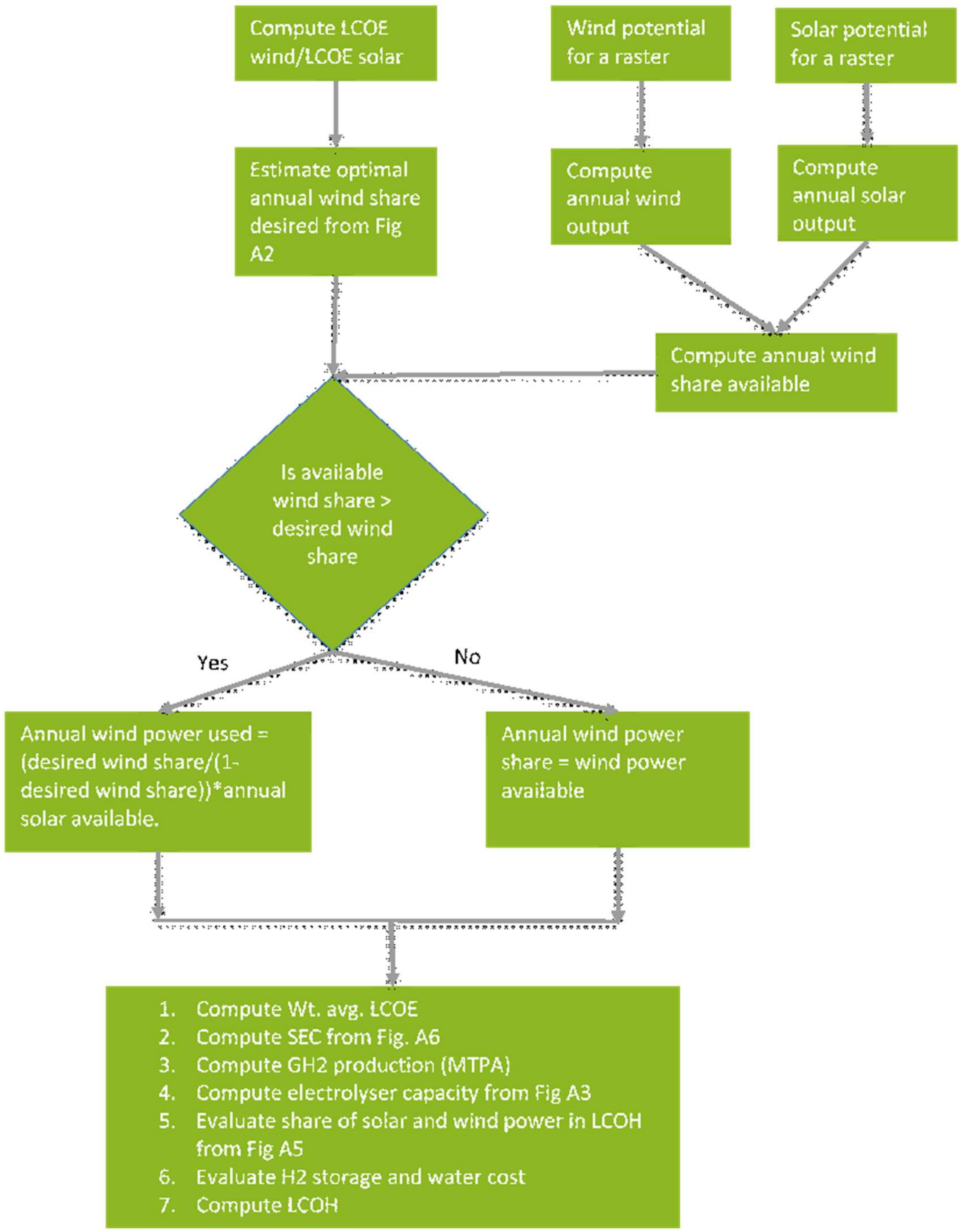


Source: Authors' analysis

Hydrogen or energy storage is not required in bulk for a green hydrogen availability lower than 85 per cent on an annual basis. Therefore, based on our modelling study (Biswas, Yadav and Guhan 2020), we consider than hydrogen storage is ~4 per cent of the total electrolyser cost per kg of hydrogen. The cost of water is obtained assuming 37 litres of water requirement per kg of hydrogen and the district-wise water cost.

Figure A26 shows the algorithm for computing LCOH. The starting point for computing LCOH is LCOEs and the wind and solar potential and PLFs in the raster. Based on the optimal RE mix indicated in Figure A22 and the RE mix available at a particular location, the optimal wind and solar plants capacities are identified. It is seen that across most locations; the solar potential is significantly higher than the wind potential. Therefore, only the optimal WSH potential is picked up and it is assumed that the residual capacity is not used for producing green hydrogen. Subsequently, parameters like weighted average LCOE, SEC, GH2 production, electrolyser capacity are computed from the above discussions in this section. Finally, LCOH is obtained as a sum of the RE, electrolyser, H2 storage and water costs.

Figure A26 Algorithm for computing LCOH



Source: Authors' analysis

The cost of hydrogen obtained from wind and solar power individually (without hybrid) is also computed in a manner similar to the wind-solar hybrid case indicated in this section.

Annexure XIV. Green hydrogen production is a water-intensive process

Table A11 lists the parameters considered for evaluating water consumption for green hydrogen production. The electrolyser consumes 27 litres of water per kg of hydrogen produced. Of this, 9 litres are converted into hydrogen, while 18 litres are rejected (Ohmium 2022). It is seen that the electrolyser needs demineralised water (DM) to produce green hydrogen. We assume that the rejection rate of the DM plant is 20 per cent. For solar-only and wind-solar hybrid powered green hydrogen plants, water is also consumed for cleaning of solar panels. Based on industry inputs, we assume that 8 litres of water is used per kW of solar installed capacity, and the panels are cleaned twice a month. This roughly corresponds to the water consumption of 85 litres per MWh. Most electrolysers today are air cooled. Hence, we do not consider any water requirement for electrolyser cooling.

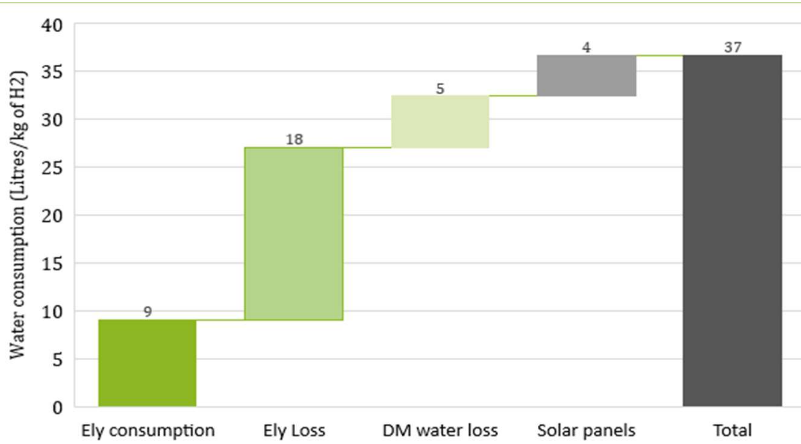
Table A11 Plant sizing parameters for green hydrogen production

Sr. No.	Parameter	Unit	Value	Reference
1	Water converted to hydrogen	Litres/kg of H2	9	(Ohmium 2022)
2	Water rejected by electrolyser	Litres/kg of H2	18	
3	Water used for cleaning solar panels	Litres/kW	8	Assumption
4	No. of cleaning cycles per month	Nos.	2	Assumption
5	Water loss in the demineralisation plant	per cent	20	(Younos 2005)

Source: Authors' compilation

Figure A27 shows the breakup of the water consumption for green hydrogen production. It is expected that about 35-40 litres of water will be consumed per kg of green hydrogen produced. The water consumption can reduce if the electrolyser reject is recycled. It should be noted that the electrolyser reject is demineralised water. Therefore, recycling this DM water depends on the technology available and might have additional economic repercussions. The water consumption associated with the cleaning of solar panels can be reduced if wind power is used to drive the electrolyser. Water consumption for solar panel cleaning can also be eliminated if robotic cleaners are used.

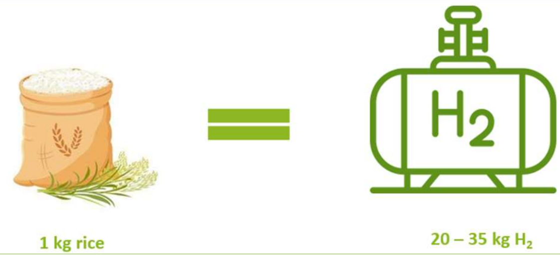
Figure A27 Water consumption in the green hydrogen production process



Source: Authors' analysis

The growth of green hydrogen economy might cause water-related conflicts in agricultural areas that have water scarcity. We compare the water intensity of green hydrogen with one of the largest produced cereals in India (rice) to assess the potential impact the green hydrogen might have on the agricultural sector. Studies (NABARD 2018) indicate that, on a national level, 737 litres of water is consumed to produce one kg of rice. Therefore, assuming a water intensity of 20 (with reuse of electrolyser reject) to 35 (without reuse of electrolyser reject), we estimate that about 20-35 kg of green hydrogen can be obtained in the water required to produce one kg of rice. The absolute value of green hydrogen that can be produced in one kg of rice depends on the variation in water intensity across various states in India.

Figure A28 Comparison of water intensity of rice and green hydrogen



Source: Authors' analysis

How does the cost of producing green hydrogen vary with the use of saline or brackish water?

Fresh water availability can be a challenge in arid and semiarid areas that are suitable for large-scale production of green hydrogen. In such cases, water for green hydrogen projects can be obtained from the sea or even underground brackish reserves. The salinity of brackish water can be converted into fresh water by reverse osmosis (RO) process. Studies indicate that 2 litres of seawater are needed to produce 1 litre of clean water, implying a rejection rate of 50 per cent. The corresponding power consumption in the RO plant is 3.5 – 5 kWh per m3 of clean water (Beswick, Oliveira and Yan 2021). The cost of clean water obtained from the desalination of seawater ranges from 0.26-2.6 USD per m3 (Curto , Franzitta and Guercio 2021). Further, the cost of converting fresh water into demineralised water is about 1.5 USD per m3 (Fu, et al. 2010). Thus, assuming a water intensity of 37 litres per kg of green hydrogen, the cost of green hydrogen is expected to increase by 1.6 – 4 per cent assuming desalinated water cost of 0.26-2.6 USD per m3 (Table A12).

Table A12 Green hydrogen cost increases by up to 1.6 - 4 per cent due to desalination and demineralisation

Sr. No.	Parameter	Unit	Value	Reference
1	Cost of seawater	INR per litre	0	
2	Cost of producing clean water from seawater	INR per litre	0.02-0.2	(Beswick, Oliveira and Yan 2021) (Curto , Franzitta and Guercio 2021)
3	Cost of producing demineralised water from clean water	INR per litre	0.1	(Fu, et al. 2010)
4	Amount of water needed to produce green hydrogen	Litres per kg of hydrogen	37 (max)	From Figure 1
5	Increase in green hydrogen cost due to the water cost	USD per kg of hydrogen	0.06-0.14*	From Sr. No. 2,3 and 4 in this table
6	Cost of green hydrogen	USD per kg	3.48	Assumption
7	Water cost share in total green hydrogen production cost	Per cent	1.6-4.0	From Sr. No. 5 and 6.

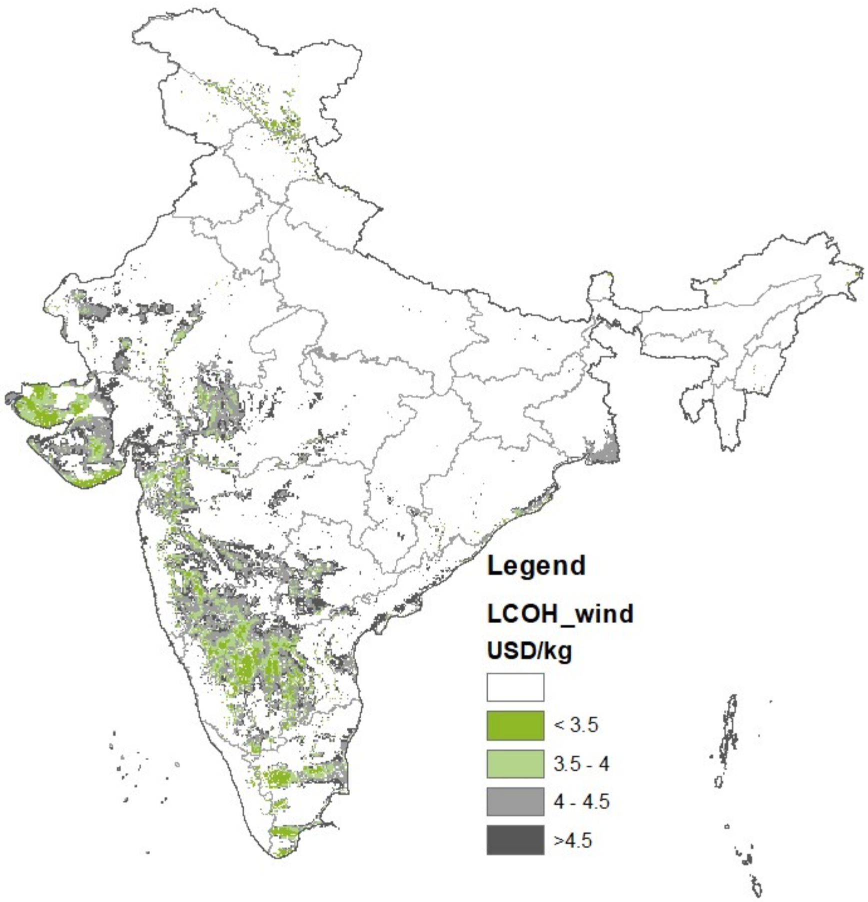
Source: Authors' compilation

* Assuming USD to INR conversion of 75

Annexure XV. Variation in LCOH for solar-only and wind-only systems

Figure A29 shows the heat map of green hydrogen production cost in India for wind-only locations. For wind-only systems, we consider a wind PLF cut off of 25 per cent and hence the green hydrogen production costs are very high in a few areas having low wind PLF. Nevertheless, it is seen that low-cost green hydrogen using wind power can only be produced in western and southern India even with a wind PLF cut-off of 25 per cent.

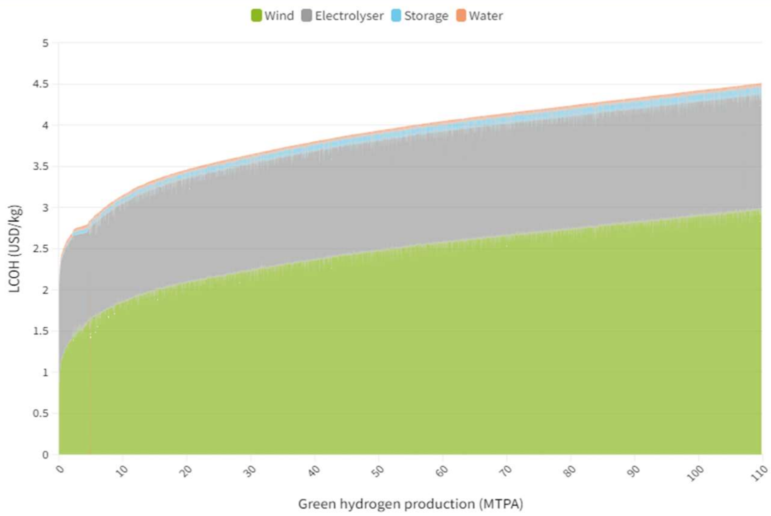
Figure A29 Variation in green hydrogen production cost with wind-only configuration



Source: Authors' analysis

Figure A30 shows the variation in hydrogen production cost with the production capacity across all wind-only areas indicated in Figure A10. It is seen that India can produce about 25 MTPA green hydrogen for a cost lower than USD 3.5 per kg. The cost of RE (wind and solar power) significantly affects the green hydrogen production cost. The effect of hydrogen storage and water cost are trivial. The green hydrogen cost increases to USD 4.5 per kg as areas with lower wind PLF are unlocked.

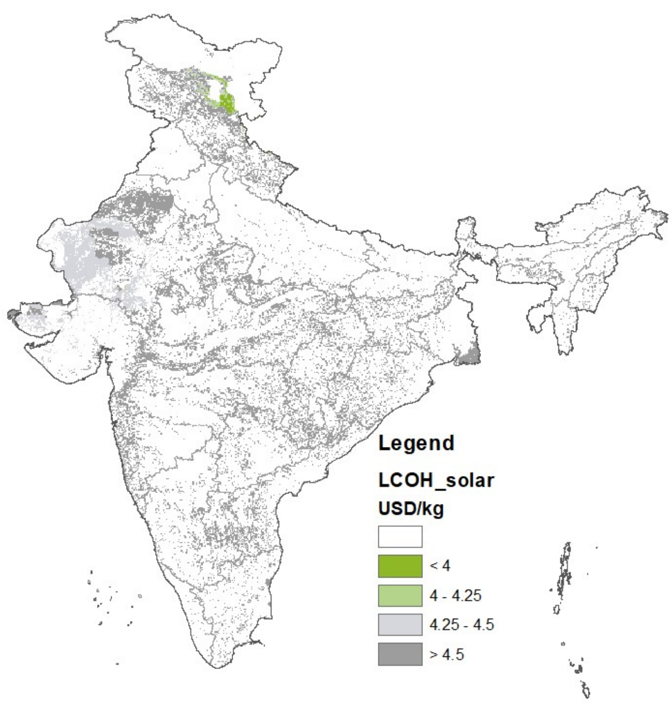
Figure A30 India can produce 25 MTPA of green hydrogen for a cost lower than USD 3.5 per kg



Source: Authors' analysis

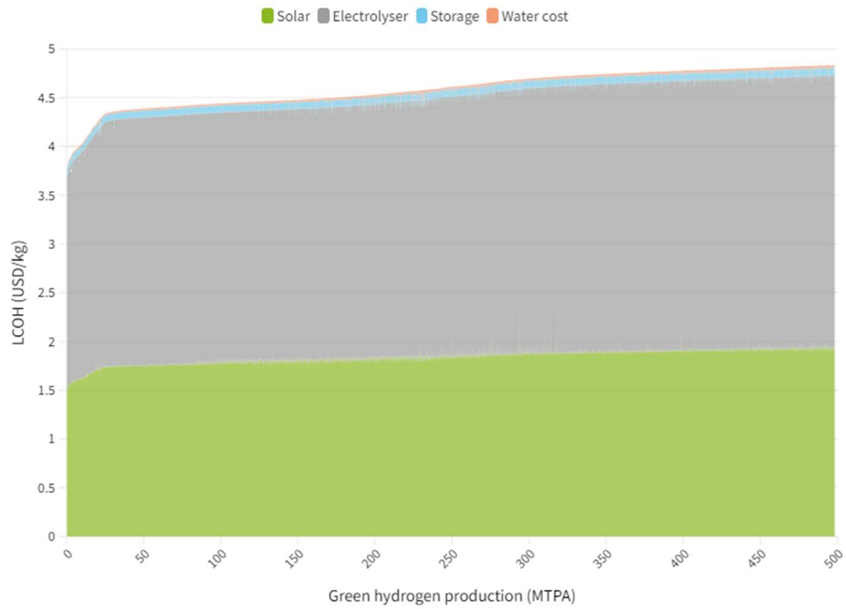
Figure A31 shows the plot of green hydrogen production cost across India. It is seen that although green hydrogen can be produced across all states in India, the production cost is significantly higher than the wind-only areas. This is primarily due to the lower utilisation of electrolyser that results in significantly higher cost of green hydrogen. Figure A32 shows the breakdown of green hydrogen production cost. Unlike WSH and wind-only scenario, the electrolysers constitute a significant share of green hydrogen cost due to the lower PLF of the electrolyser. It is also seen that unlike wind-only configuration, the cost of green hydrogen does not significantly vary across states in India. This is because the PLF and hence the LCOE of solar power remains the same across most states in the country.

Figure A31 Variation in green hydrogen production cost with solar-only configuration



Source: Authors' analysis

Figure A32 India can produce large amount of green hydrogen using solar power albeit at higher prices



Source: Authors' Analysis

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