Assessment of global potential of solar and wind energy using GIS

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NIES
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Why Renewables?

Renewable energy conversion technologies ("renewables") are expected to be suitable alternatives in a sustainable energy future for several reasons (Turkenburg, 2000)

1. Renewables lead to a diversification of energy sources by increasing the share of a diverse mixture of renewable sources, and thus to an enhanced energy security.
2. Renewables are more widely available compared to fossil fuels and therefore reduce the geopolitical dependency of countries as well as minimize spending on imported fuels.
3. Renewables contribute less to local air pollution (except for some biomass applications) and therefore reduce the human health damages.
4. Many renewable energy technologies are well suited to small-scale off-grid applications and hence can contribute to improved access of energy services in rural areas.
5. Renewables can balance the use of fossil fuels and save these for other applications and future use.
6. Renewables can improve the development of local economies and create jobs.
7. Renewables do not give rise to GHG emissions to the atmosphere.

What kind of Potential?

The **geographical** potential is the energy generated at areas that are considered available and suitable.

The **technical** potential is the geographical potential reduced by the losses of the conversion of the primary energy to secondary energy sources.

The **economic** potential is the total amount of technical potential derived at cost levels that are competitive with alternative energy applications.

The **implementation** potential is the total amount of the technical potential that is implemented in the energy system.

Today's Presentation

GIS Data used in this study

- Insolation, Wind Speed, Land Cover
- Elevation, Wilderness Area

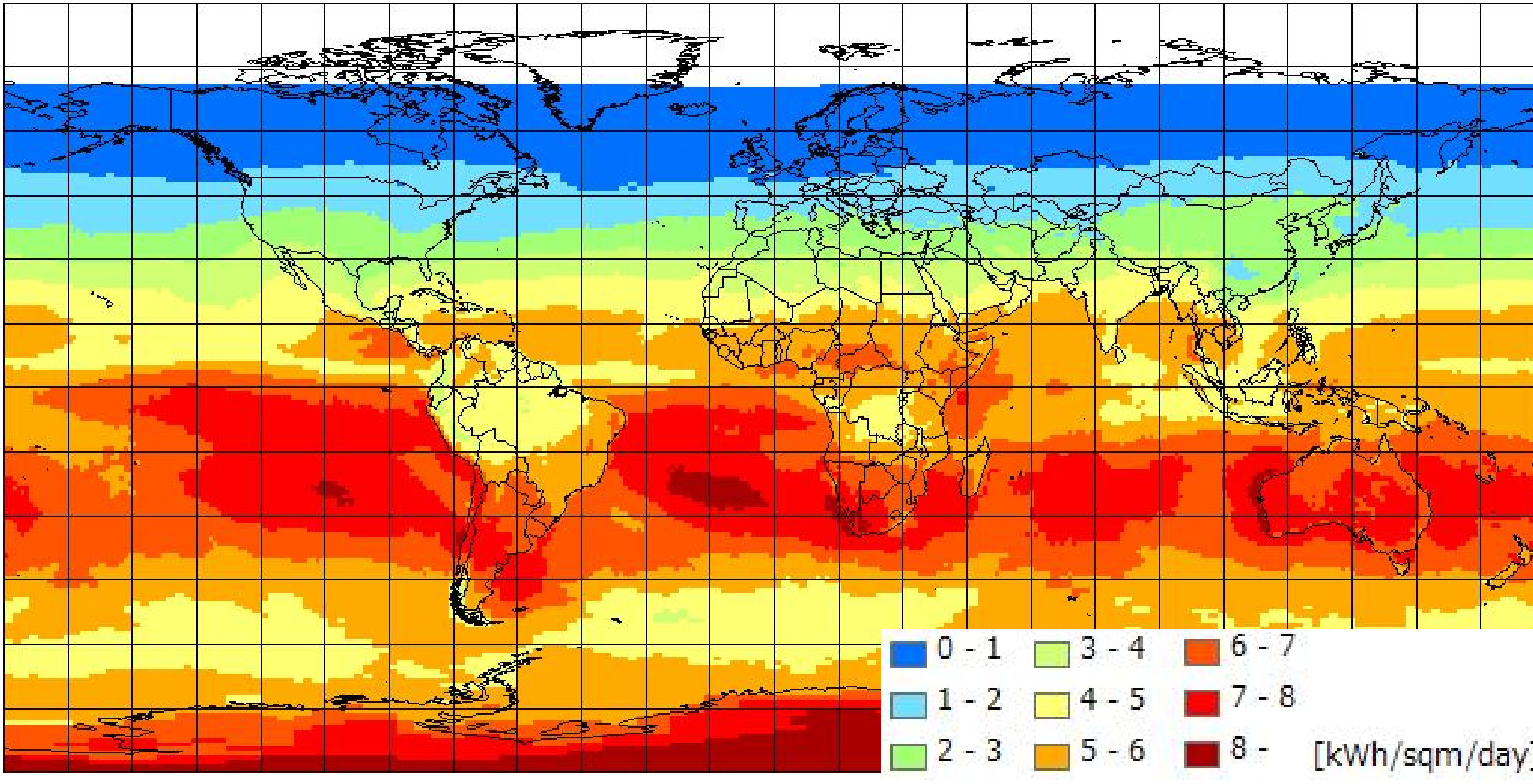
Calculation Method

- Technical Potential of Solar-PV
- Technical Potential of Onshore Wind Power

Calculation Results

- Global
- Japan, China, Korea, India, Indonesia, Malaysia, Thailand, Brazil

Monthly Averaged Insolation



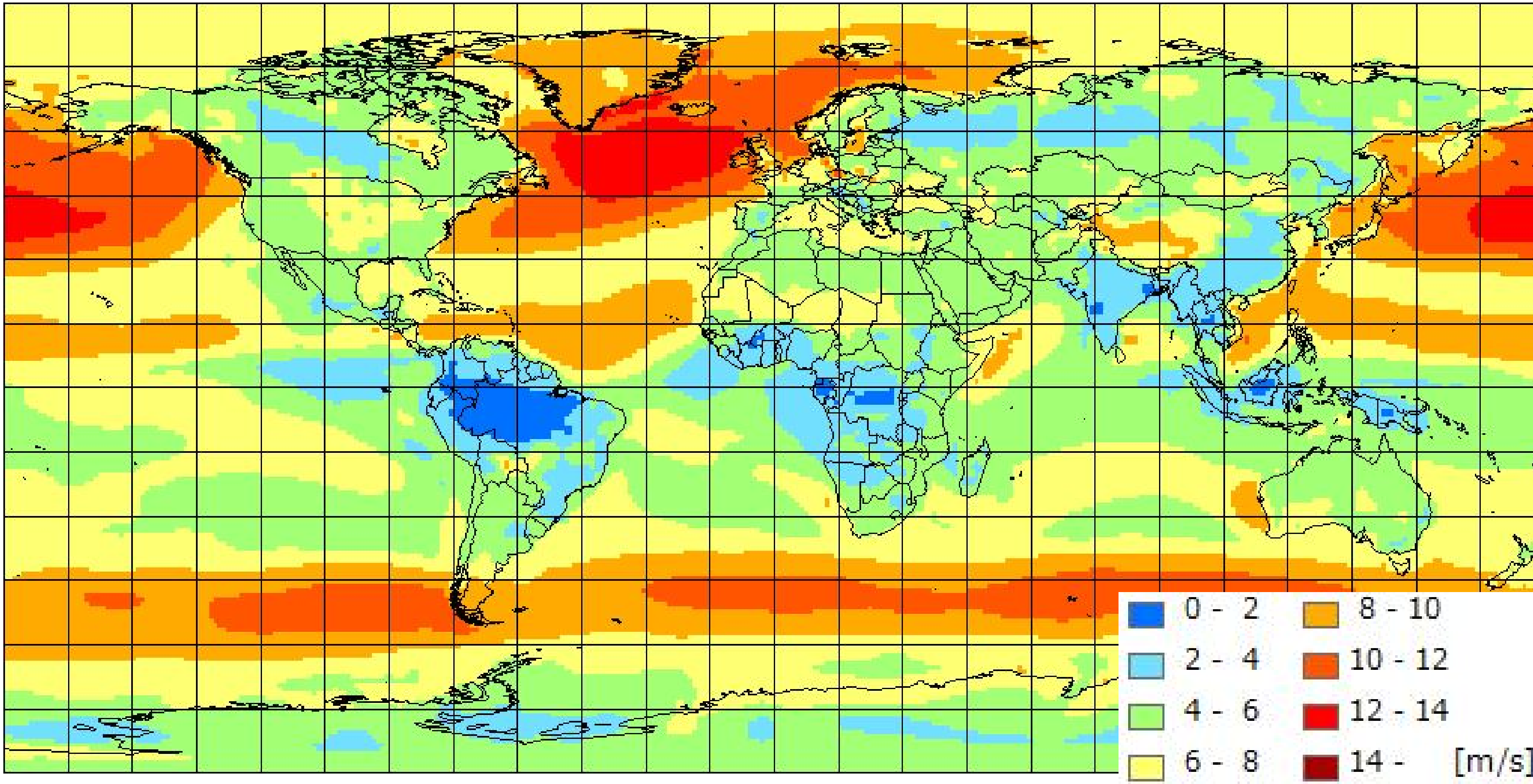
JAN

Monthly Averaged Insolation Incident On A Horizontal Surface (Monthly average for Jul 1983 – Jun 1993)

Source: NASA LaRC Atmospheric Science Data Center

Resolution: 1 deg×1deg

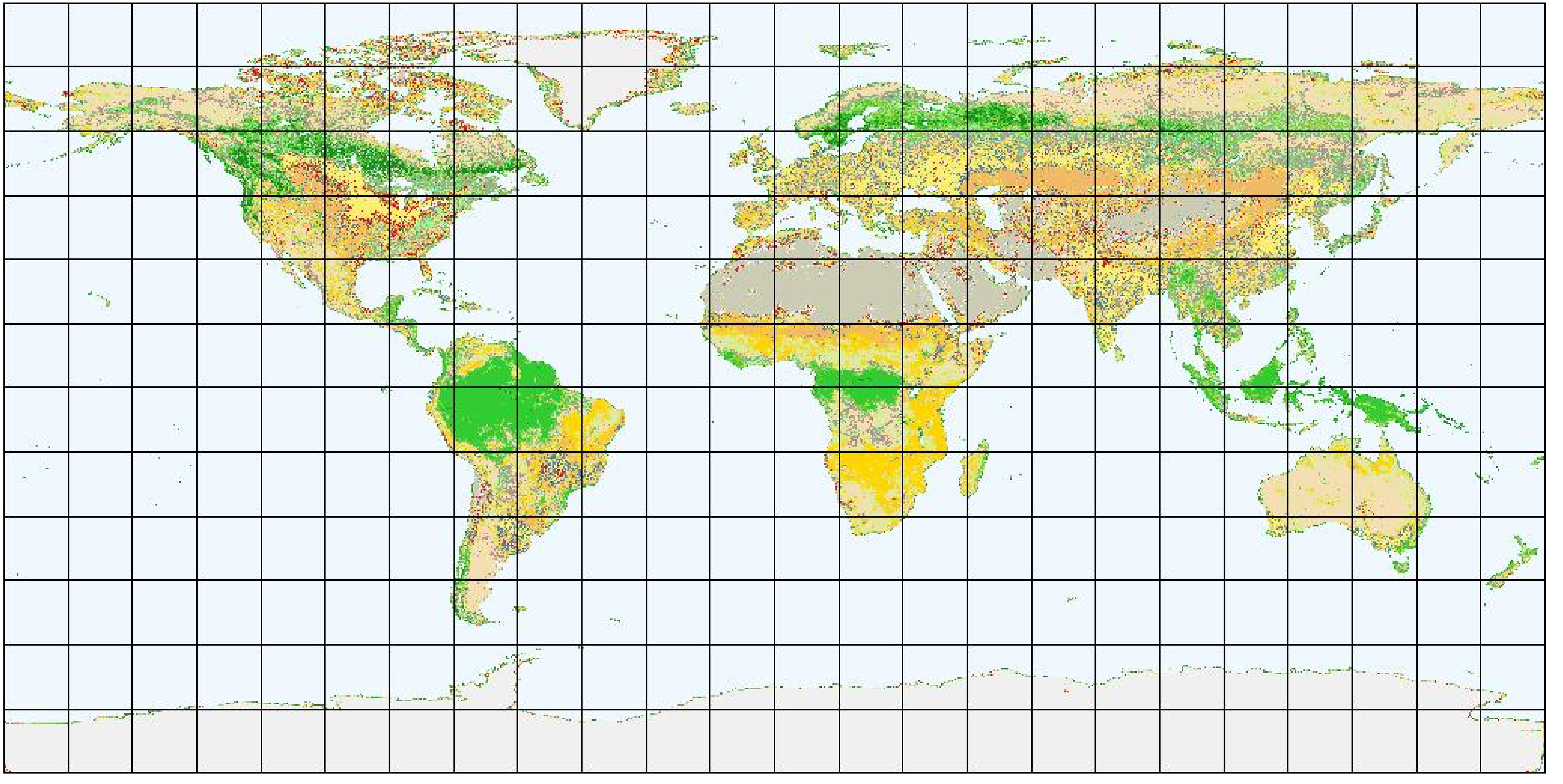
Monthly Averaged Wind Speed



JAN

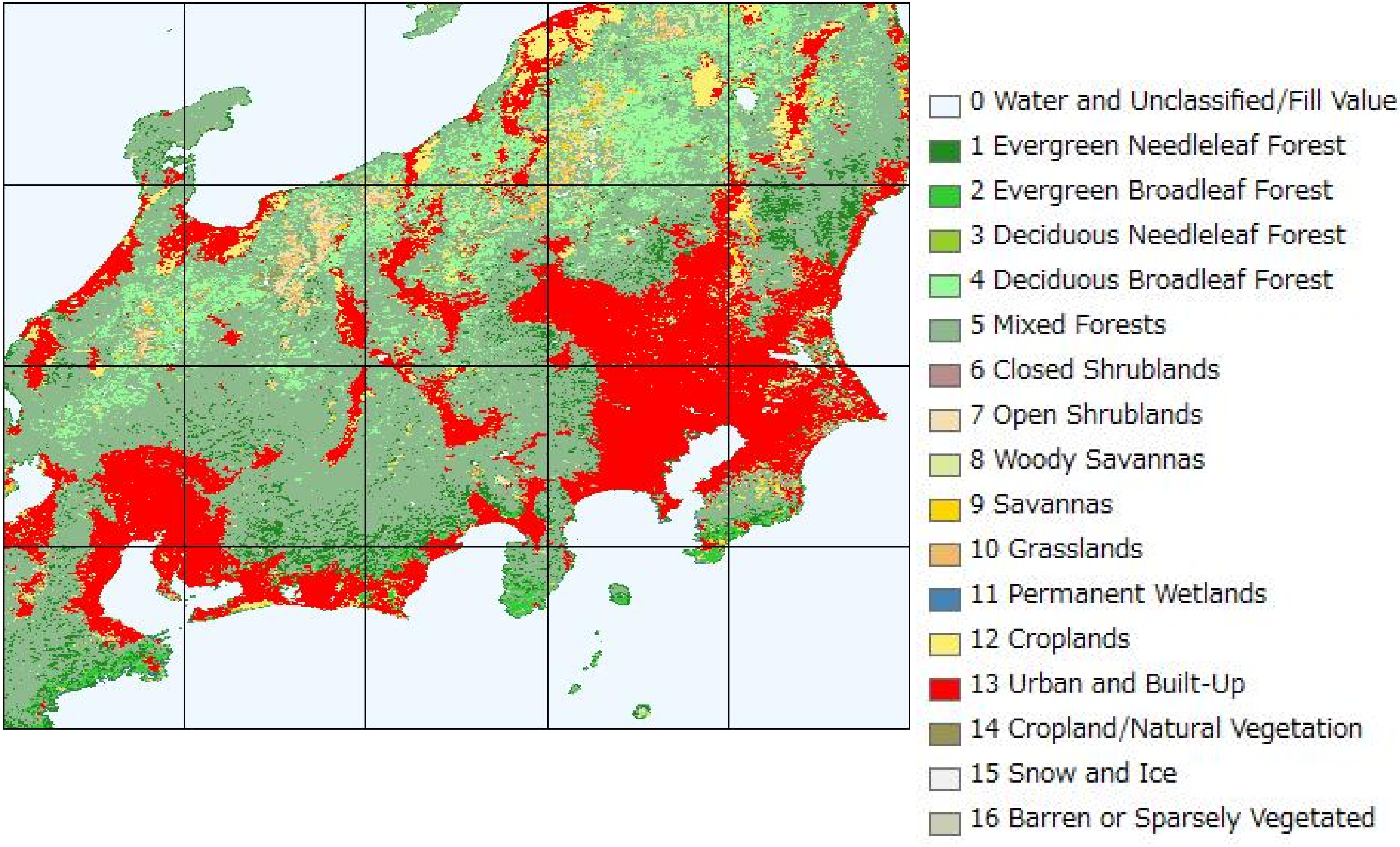
Monthly Averaged Wind Speed At 50m Above The Surface
(Monthly average for Jul 1983 – Jun 1993)
Data Source: NASA LaRC Atmospheric Science Data Center
Resolution: 1 deg×1deg

Land Cover Data

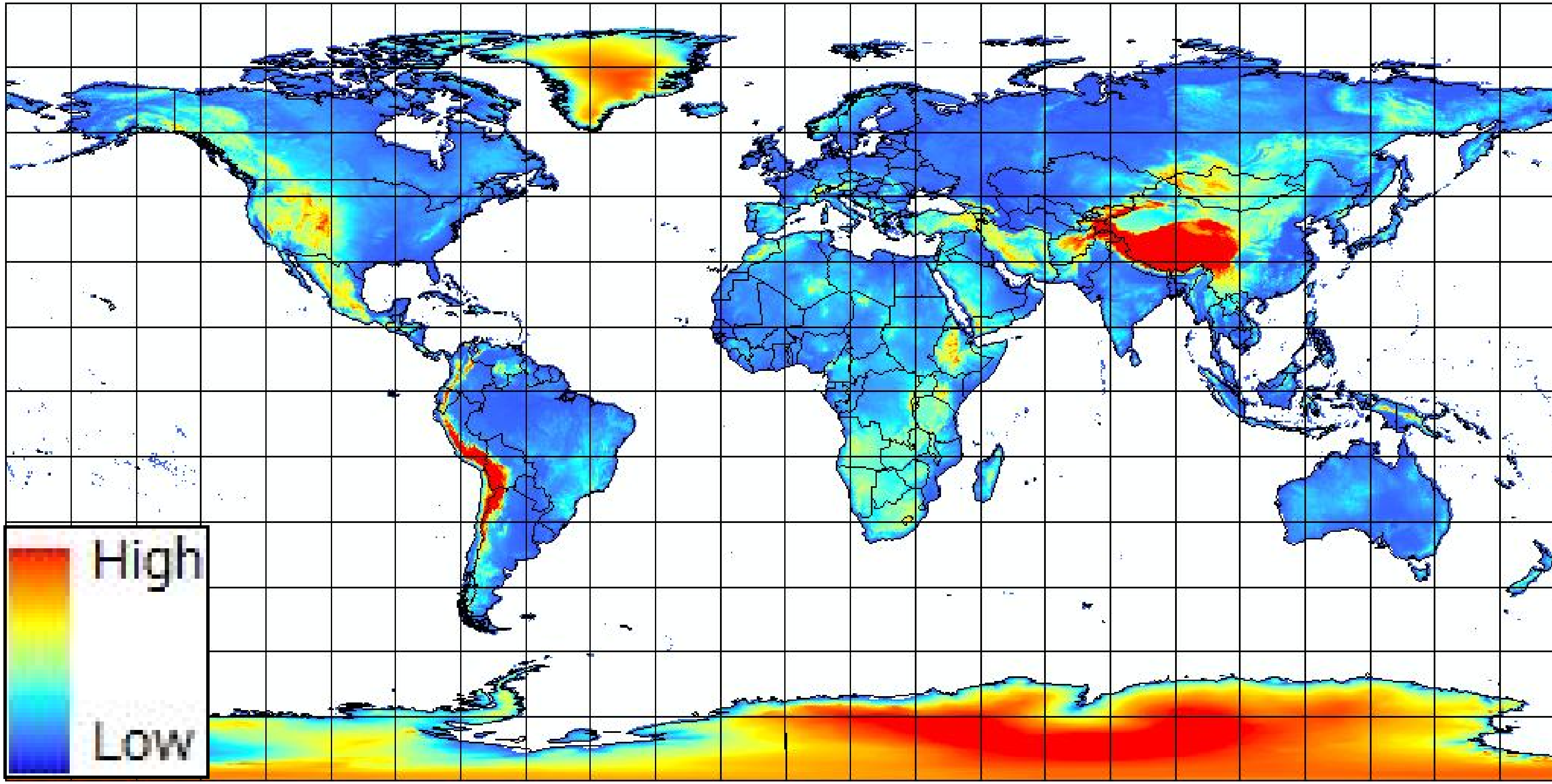


MODIS/Terra Land Cover Type Yearly L3 Global 1km
Land Cover Type 1 (IGBP), Jan 2001 - Dec 2001
Data Source: NASA Land Processes Distributed Active Archive Center
Resolution:30 sec×30 sec

Land Cover Data



Elevation Data

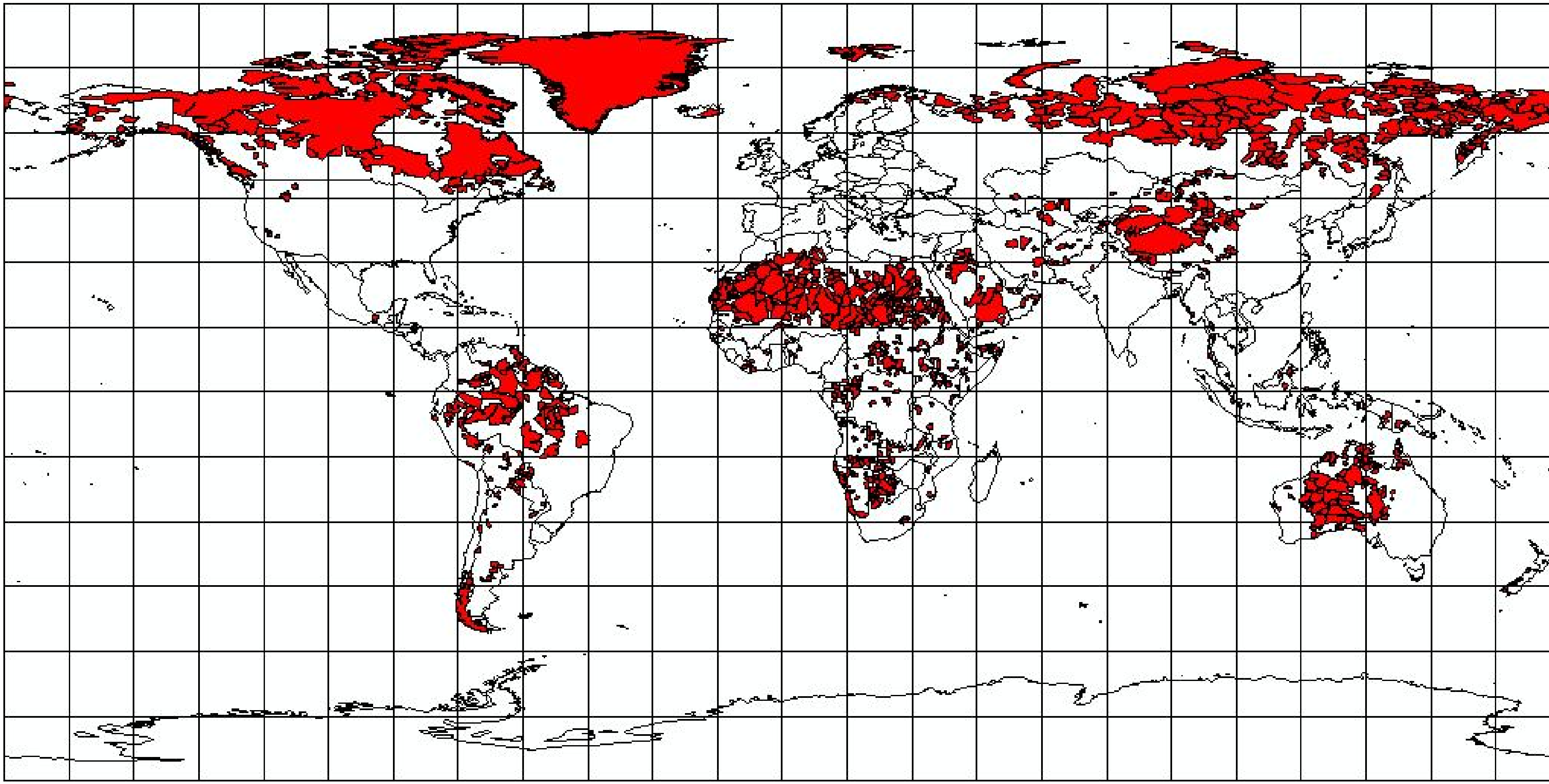


The Global Land One-km Base Elevation (GLOBE) Data

Data Source: National Geophysical Data Center (NGDC), US

Resolution:30 sec×30 sec

Wilderness Areas



World Wilderness Areas
(“undeveloped land still primarily shaped by the forces of nature”)
Data Sources: Sierra Club and World Bank, as integrated by UNEP/GRID

Calculation Methods

Employing a grid cell approach using GIS data.

We Calculated the Monthly and Hourly Potential
in 3×3 arc-minute grid cells
from averaged insolation data, averaged wind speed data, land cover type data, and other information.

	Solar-PV	Wind
Monthly Averaged Insolation	○	
Monthly Averaged Wind Speed		○
Land Cover	○	○
Elevation		○
Wilderness Areas	○	○

Available Land Area

How much we can use the land for generating power?

Land Cover	Suitability Fraction r [%]	
	Solar	Wind
All Forest (*1)	0	5
Closed Shrublands, Woody Savannas	5	10
Grasslands, Open Shrublands, Savannas	20	30
Barren or Sparsely Vegetated	20	20
Croplands, Cropland/Natural Vegetation Mosaic	2	60
Urban and Built-Up	5	0
Water Bodies, Permanent Wetlands, Snow and Ice	0	0

(*1) Evergreen or deciduous, needleleaf or broadleaf, and mixed forest are included in the "All Forest".

Calculation Methods

＜Solar-PV Technical Potential＞

$$SEP_g = \sum_{M,T} I_{g,M,T} \cdot A_g \cdot \frac{e}{100} \times 10^{-6}$$

SEP : Solar-PV Energy Potential [GWh/yr]
I : Insolation on optimum inclination angle[kW/m^2]
A : Available Area[m^2] , *e* : Solar-PV module efficiency = 13.0 [%]
g : grid cell, *M* : monthly, *T* : hourly

Solar elevation angles, solar azimuth angles, slopes and elevation angles of land surface are taken into account.

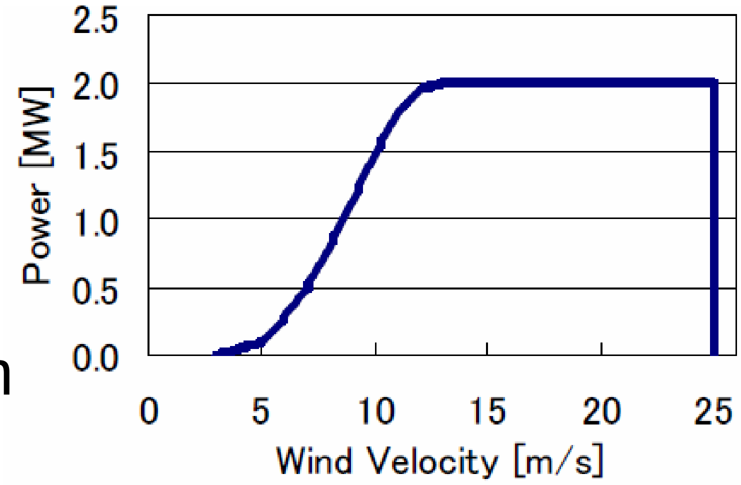
Optimum inclination angle of solar-PV cell are calculated for each grid cell.

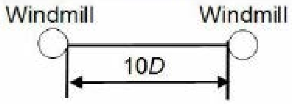
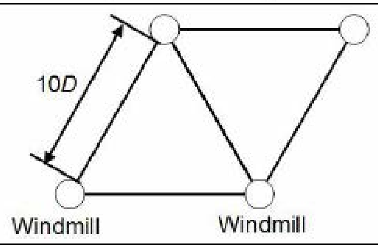
These procedures allow more accurate evaluation of the solar and wind energy potential.

Calculation Methods

＜Windmill＞

Rated Power : 2MW
Hub Height : 80m
Rotor Diameter : 90m
Upper Limit of Elevation : 2000m
Upper Limit of Slope : 60%



Number of Windmills	Required Area	Configuration
1	$2D \times 2D$	
2	$12D \times 2D$	
3 and above	$(N\text{-}2) \times (1/2) \times 11D \times 11D \times \sin(\pi/3)$	

(D is the roter diameter. N is the number of windmills.)

Calculation Methods

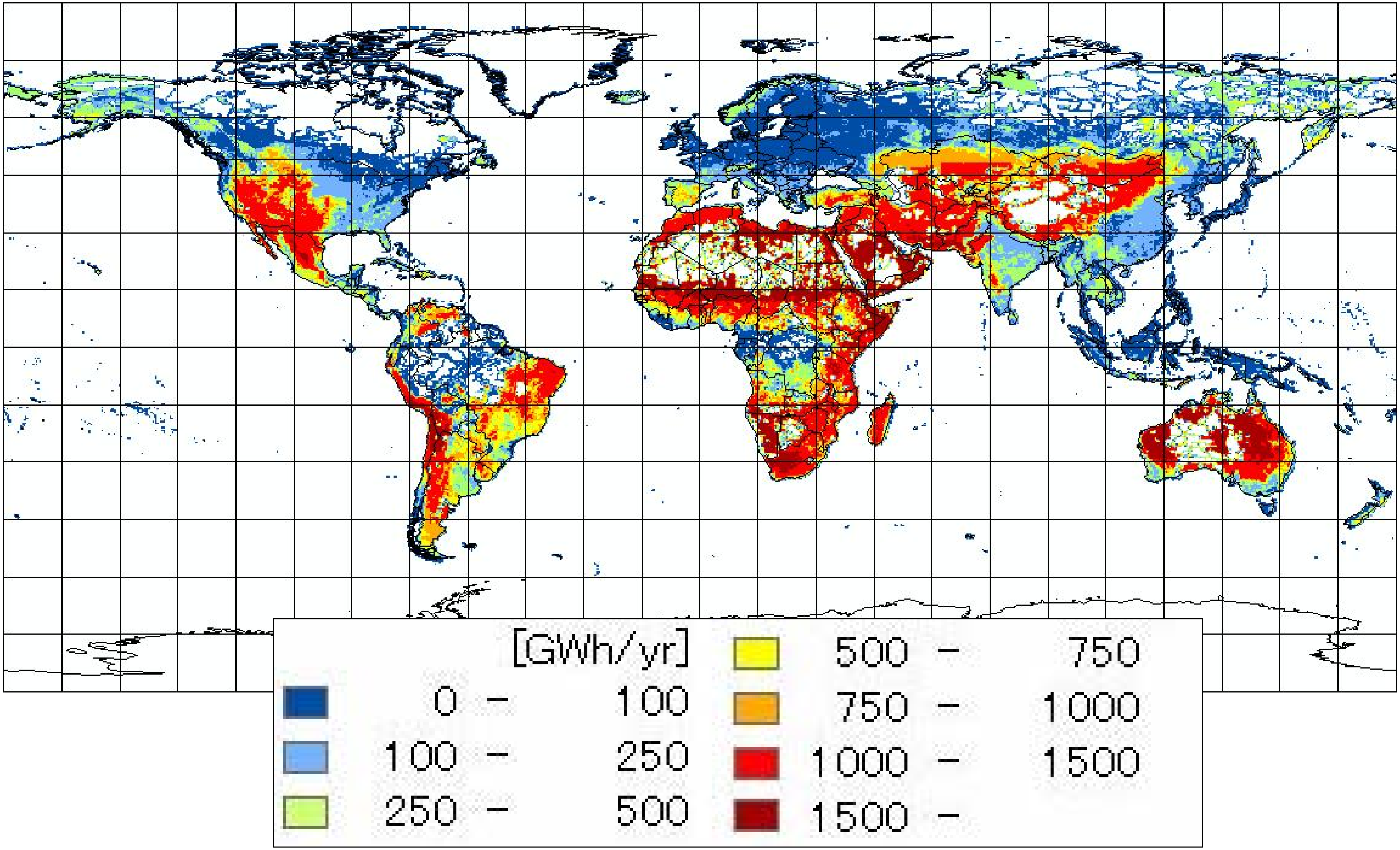
＜Wind Power Technical Potential＞

$$WEP_g = \sum_{v,LC} P(v) \cdot R(v) \cdot 8760 \cdot j \cdot k_{LC} \cdot (1 - l) \cdot Nw_{g,LC}$$

WEP : Wind Energy Potential [GWh/yr]
$P(v)$: Power at v [m/s] wind speed
$R(v)$: Incidence Rate of v [m/s] wind speed (Rayleigh Distribution)
j : Available Rate of Windmill = 95 [%], k : Correction Factor
l : other losses = 5.0 [%], Nw : Number of Windmill
LC : land cover type

Land Cover	Power Correction Factor k
All Forest (*1)	0.90
Closed Shrublands, Woody Savannas	0.90
Grasslands, Open Shrublands, Savannas	0.95
Barren or Sparsely Vegetated	0.95
Croplands, Cropland/Natural Vegetation Mosaic	0.90

Solar-PV Technical Potential

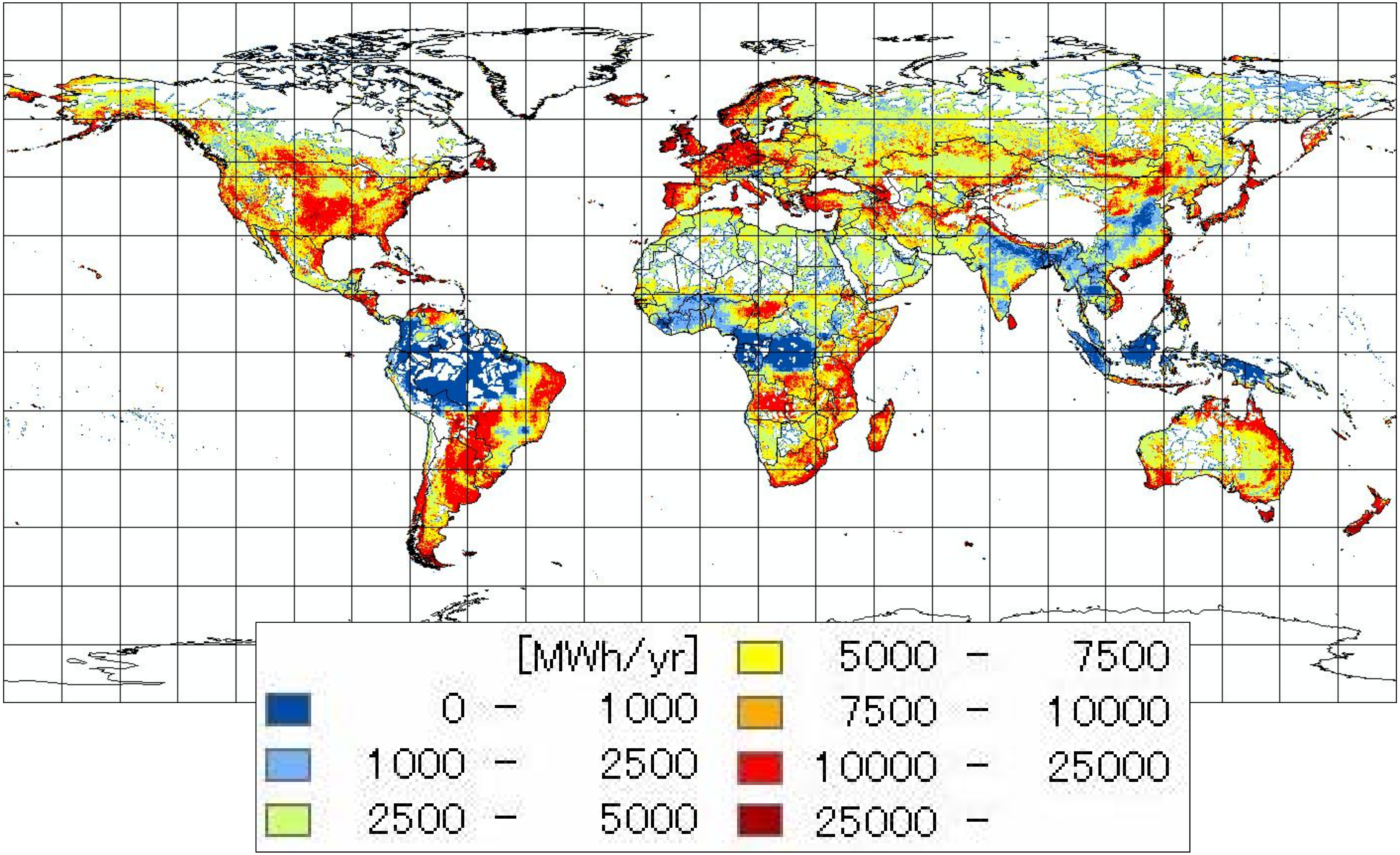


Solar-PV Technical Potential

Country Name	Solar Energy Potential [TWh/yr]			
	Grade I 0-1800 $kWh/m^2/yr$(*1)	Grade II 1800-2200 $kWh/m^2/yr$(*1)	Grade III 2200-2600 $kWh/m^2/yr$(*1)	Total
Japan	1512	39	0	1551
China	47703	124606	780	172934
South Korea	210	374	0	584
India	4479	40383	1237	46099
Pakistan	3789	25534	4006	33329
Indonesia	2162	3451	874	6487
Thailand	36	5082	0	5118
Malaysia	206	286	0	492
Saudi Arabia	0	24189	48474	72663
Australia	1252	111988	128348	241588
New Zealand	3091	180	0	3271

(*1) is Insolation on optimum inclined angle of solar cell module

Wind Power Technical Potential

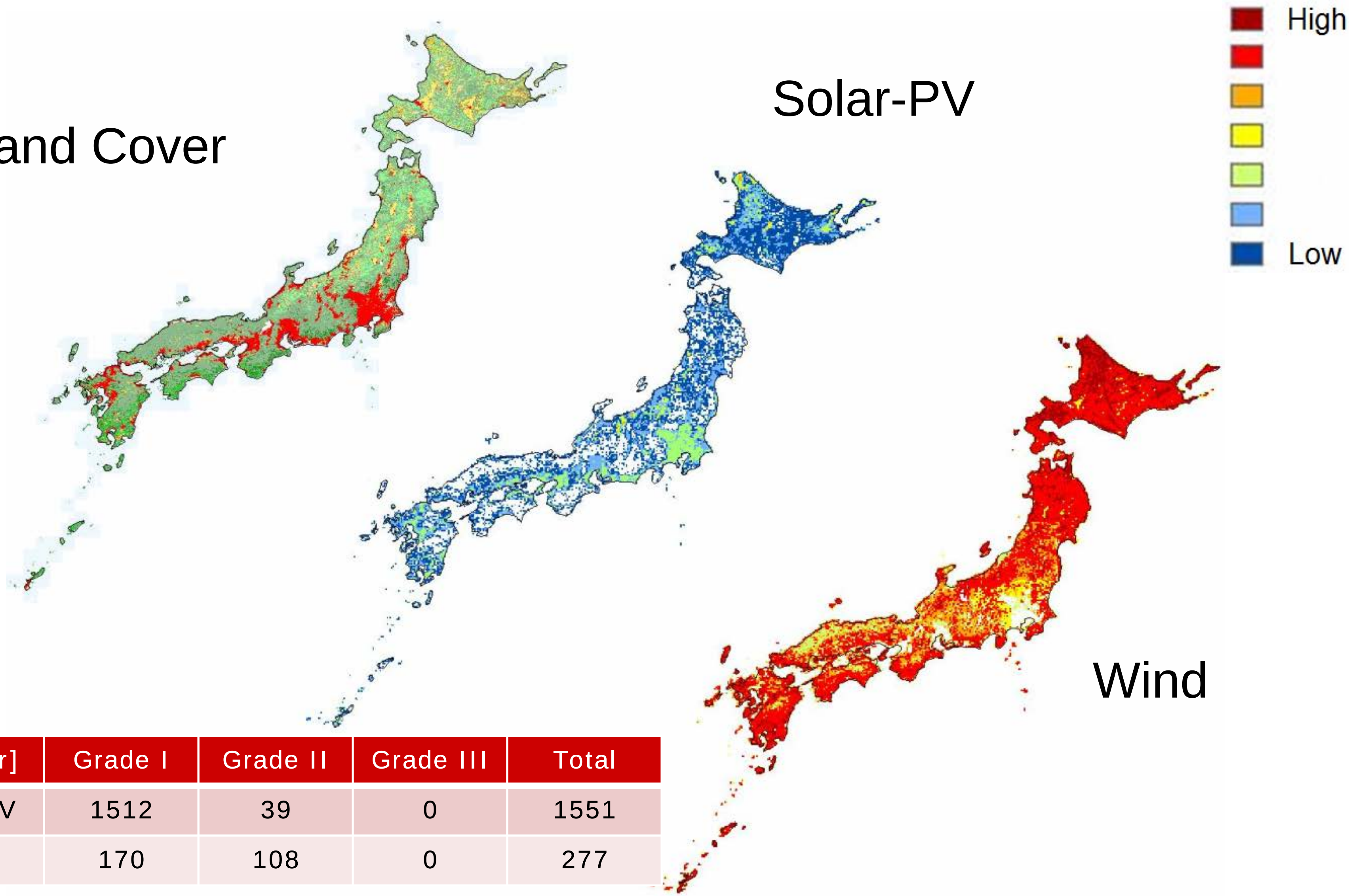


Wind Power Technical Potential

Country Name	Wind Energy Potential [TWh/yr]			
	Grade I 0-30 %(*2)	Grade II 30-40 %(*2)	Grade III 40-100 %(*2)	Total
Japan	170	108	0	277
China	1259	126	8	1393
South Korea	48	3	0	51
India	412	4	0	416
Pakistan	147	1	0	149
Indonesia	198	0	0	198
Thailand	46	0	0	46
Malaysia	15	0	0	15
Saudi Arabia	175	0	0	175
Australia	1528	265	7	1800
New Zealand	74	104	84	262

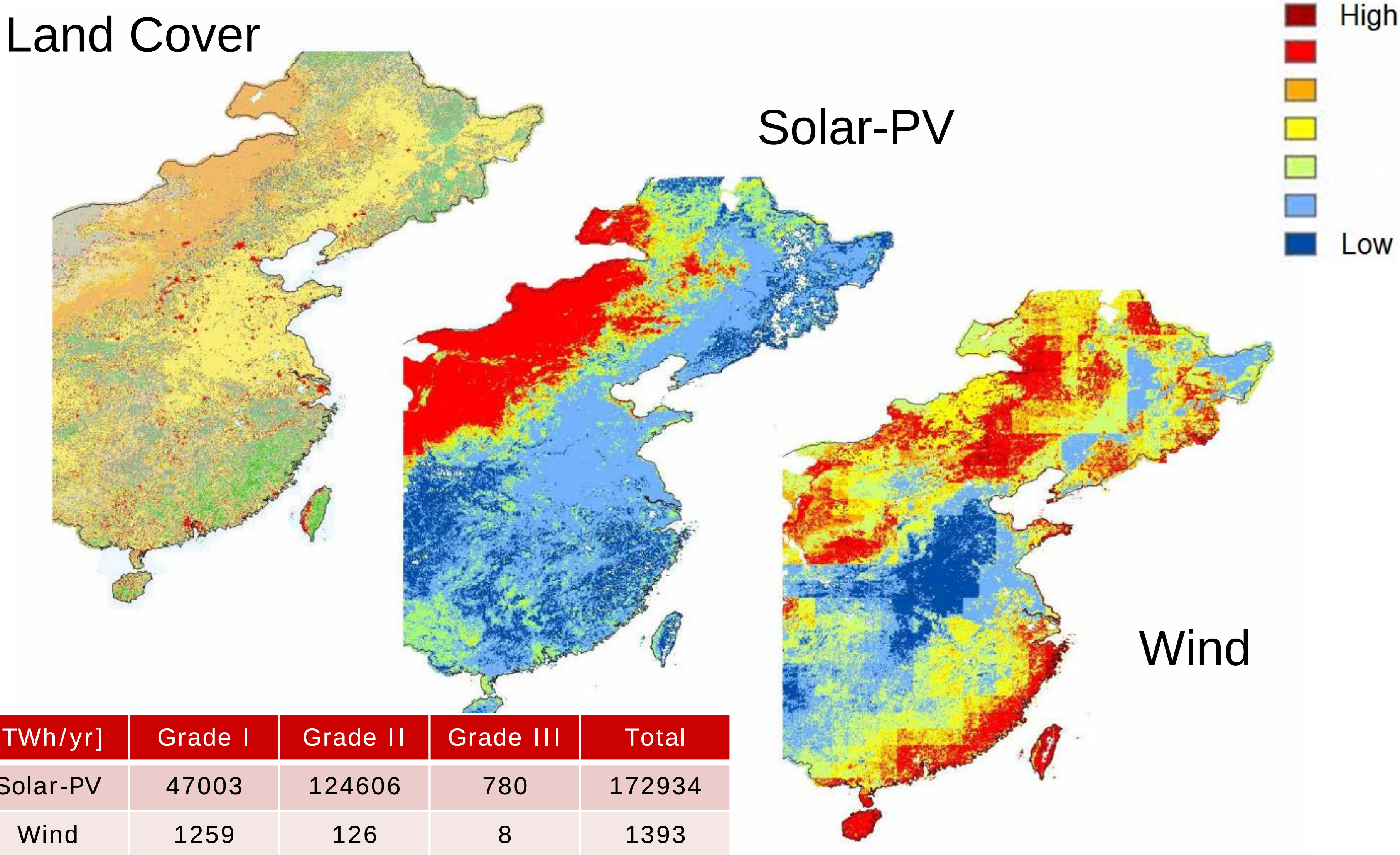
(*2) is utilized capacity of wind power system.

Japan



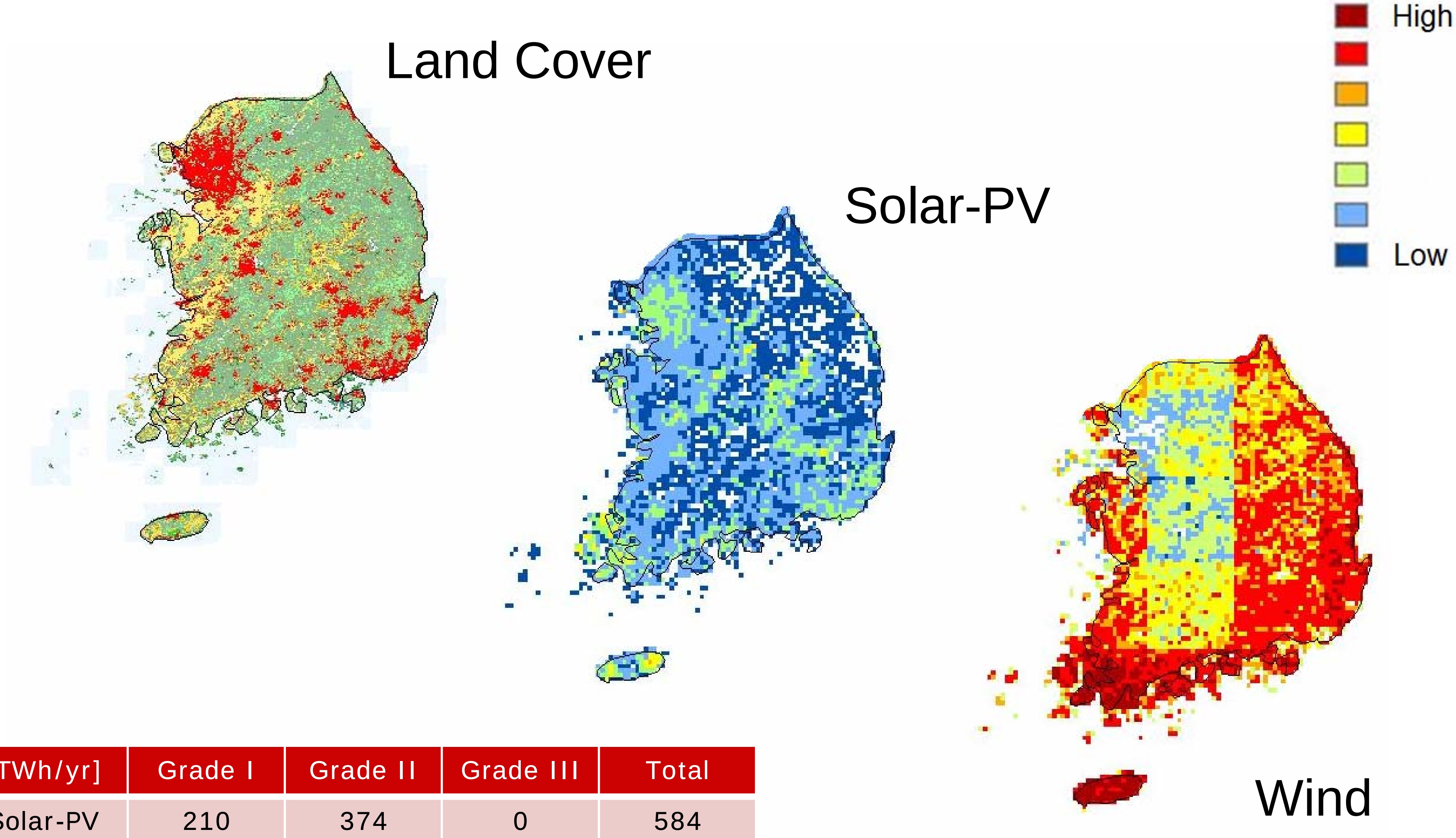
[TWh/yr]	Grade I	Grade II	Grade III	Total
Solar-PV	1512	39	0	1551
Wind	170	108	0	277

China



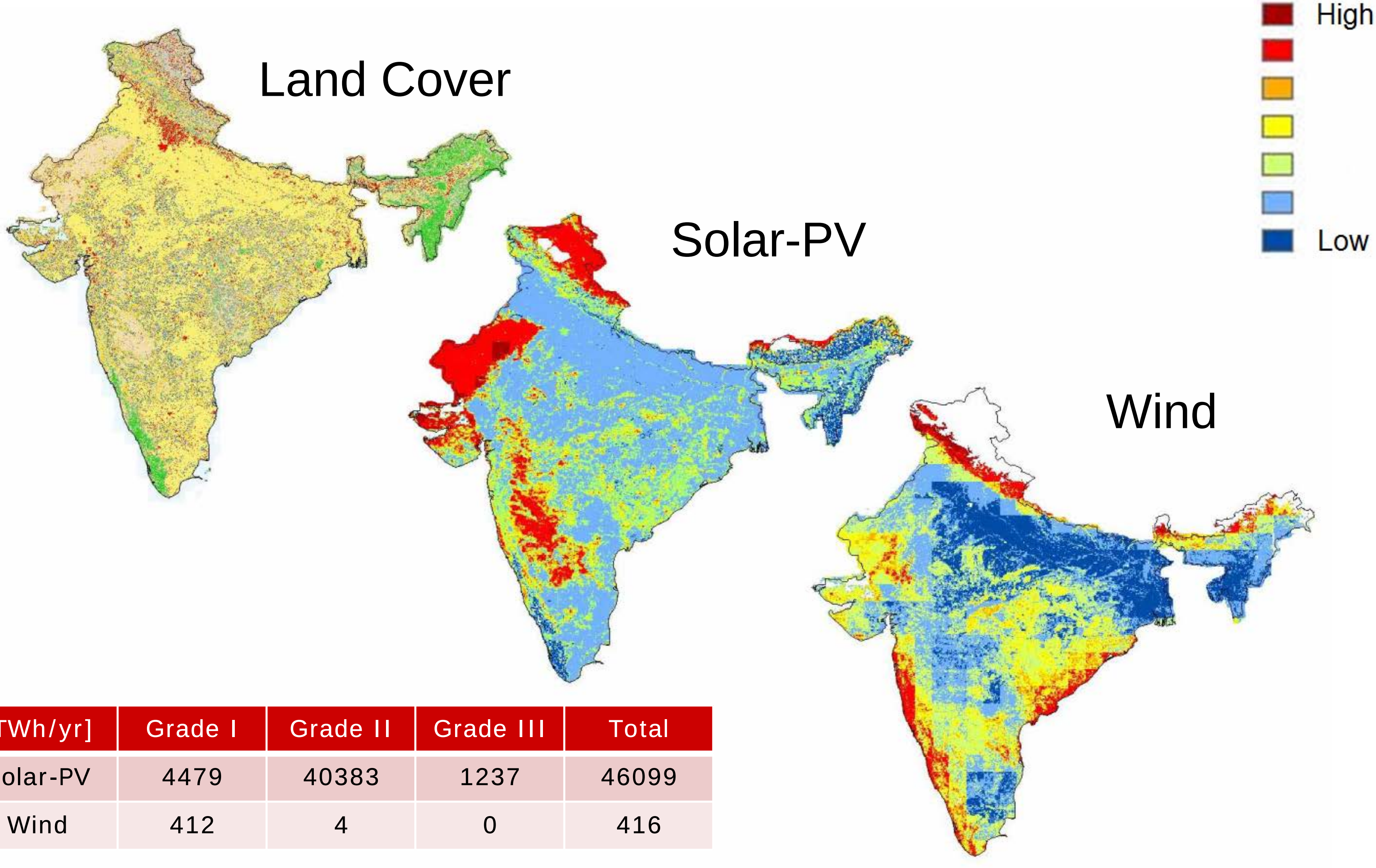
[TWh/yr]	Grade I	Grade II	Grade III	Total
Solar-PV	47003	124606	780	172934
Wind	1259	126	8	1393

Korea



[TWh/yr]	Grade I	Grade II	Grade III	Total
Solar-PV	210	374	0	584
Wind	48	3	0	51

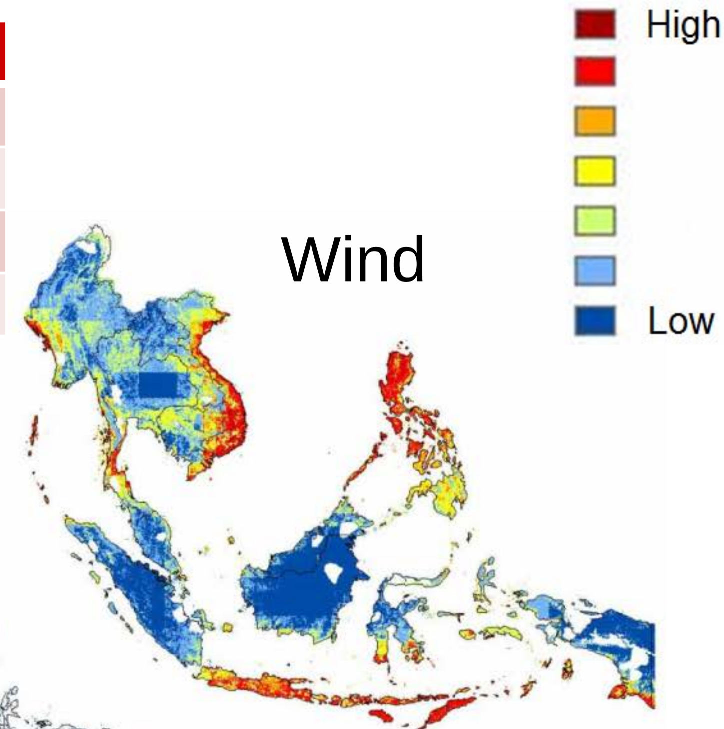
India



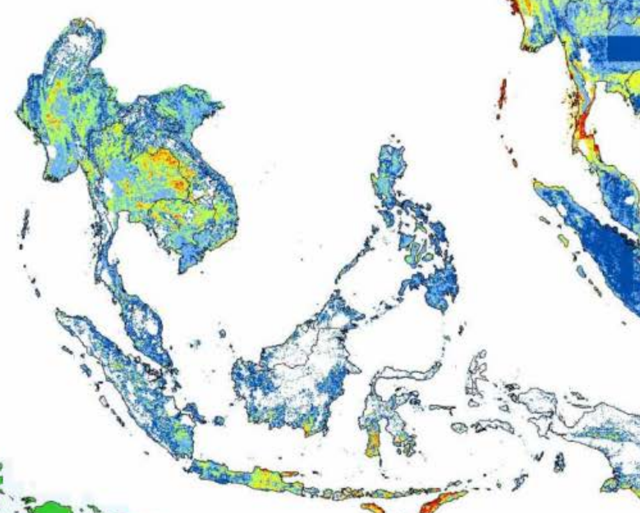
[TWh/yr]	Grade I	Grade II	Grade III	Total
Solar-PV	4479	40383	1237	46099
Wind	412	4	0	416

South East Asian Countries

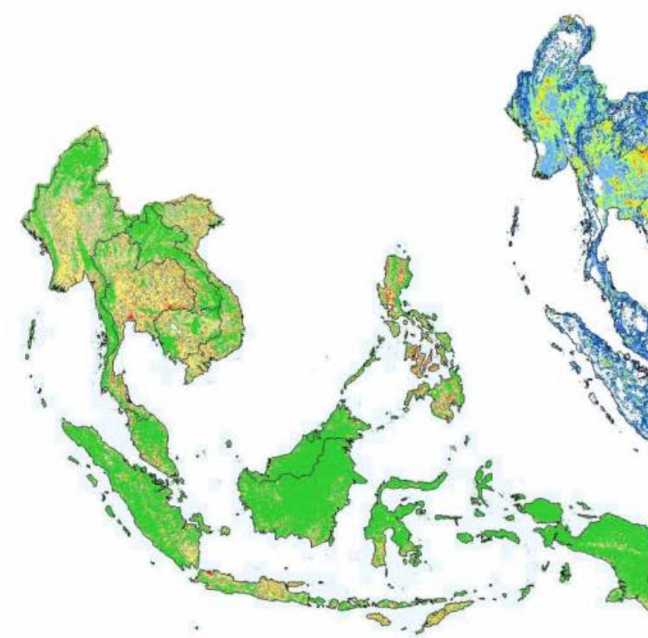
	[TWh/yr]	Grade I	Grade II	Grade III	Total
Thailand	Solar-PV	36	5082	0	5118
	Wind	46	0	0	46
Malaysia	Solar-PV	206	286	0	492
	Wind	15	0	0	15



Wind



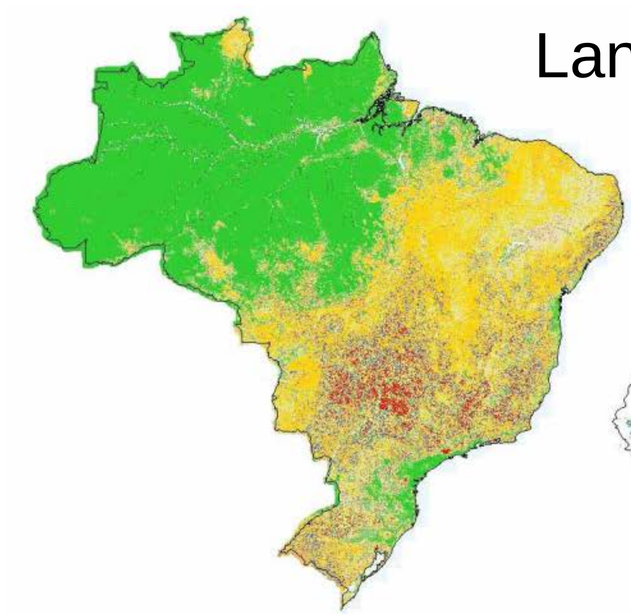
Solar-PV

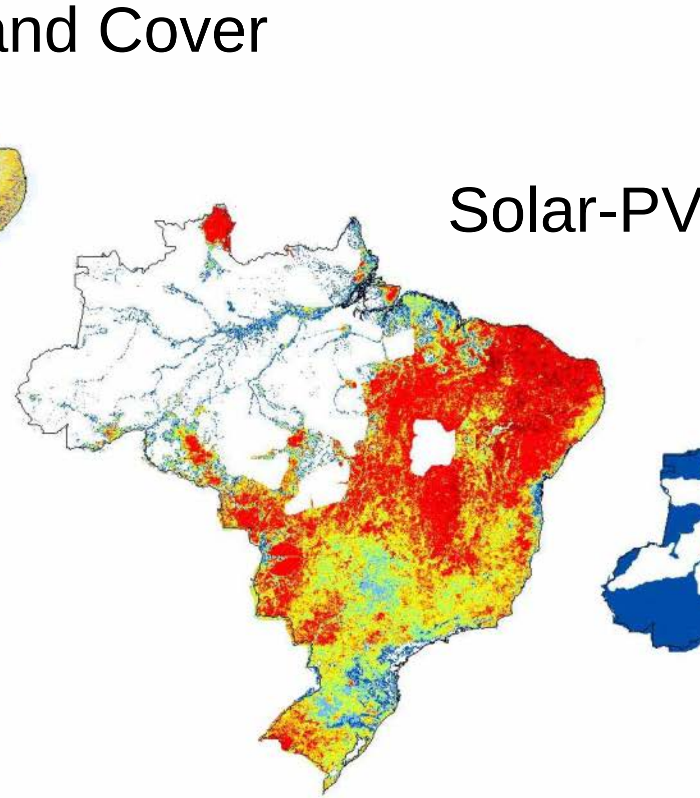


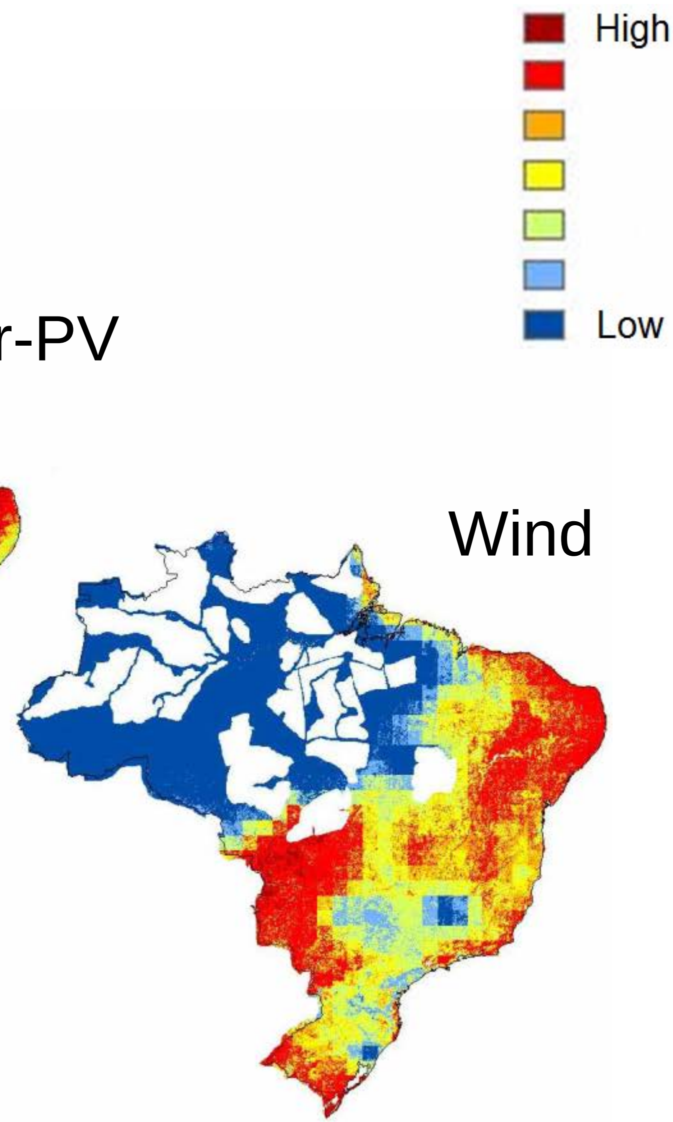
Land Cover

	[TWh/yr]	Grade I	Grade II	Grade III	Total
Indonesia	Solar-PV	2162	3451	874	6487
	Wind	198	0	0	198

Brazil







[TWh/yr]	Grade I	Grade II	Grade III	Total
Solar-PV	21339	114501	195	136035
Wind	1190	45	0	1235

Next Step

Technical Potential

Off shore wind

Economic Potential

Production cost

Operational cost

Asian Country

Country-by-Country

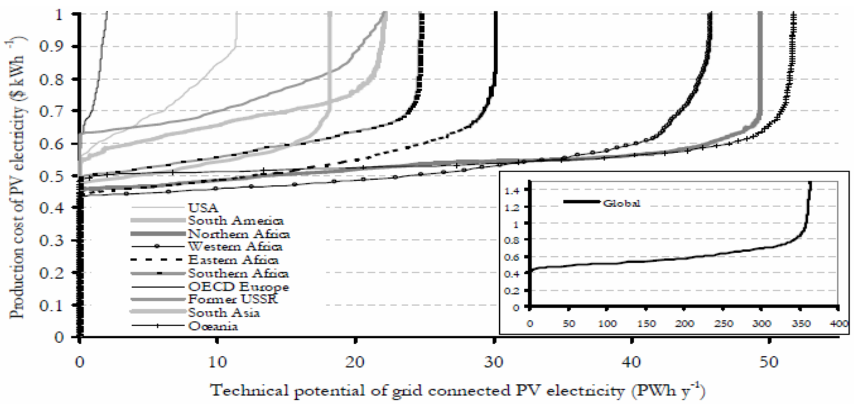


Figure 8: Cost-supply curve for grid-connected centralised PV applications, globally, and for ten regions (present situation).

(Hoogwijk, 2004)

Implementation Potential

Information for subsidies and other policy incentives

Thank you very much !