IESR

Solar Potential Report Launch

Beyond 207 Gigawatts: Unleashing Indonesia's Solar Potential

Nationwide solar potential assessment based on geographic information system (GIS) mapping

Thursday, March 18, 2021

Supported by: Global Environmental Institute 北京市朝阳区永续全球环境研究所

Media partner: SolarHub by Institute for Essential Services Reform

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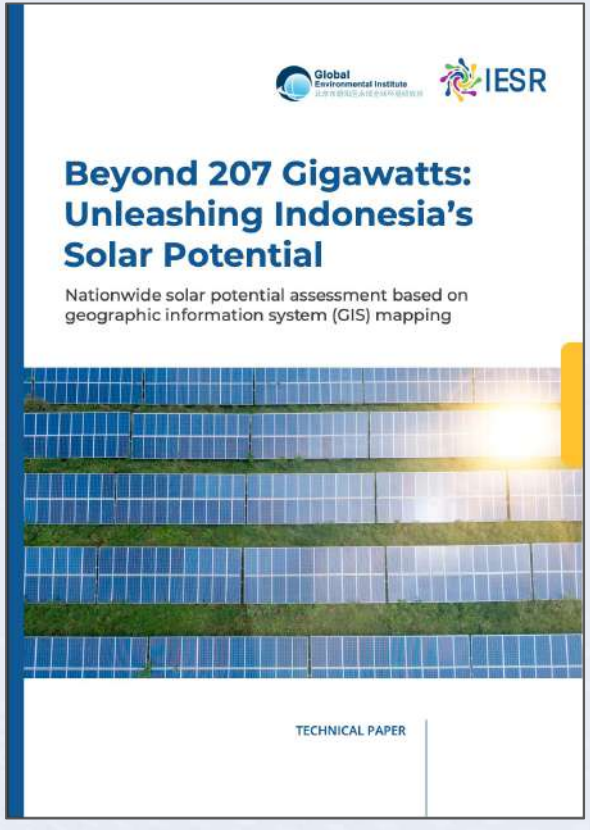
Data sources:

Geospatial Information Agency (*Badan Informasi Geospasial*, BIG), with the support from the Directorate of Various New and Renewable Energy (Direktorat Aneka EBT) of MEMR, Indonesia

About the report

1. Introduction
2. Methods
3. Results
4. Discussion
5. Conclusion and Recommendations



You can download the report **at the end** of today's report launch on our website (www.iesr.or.id).

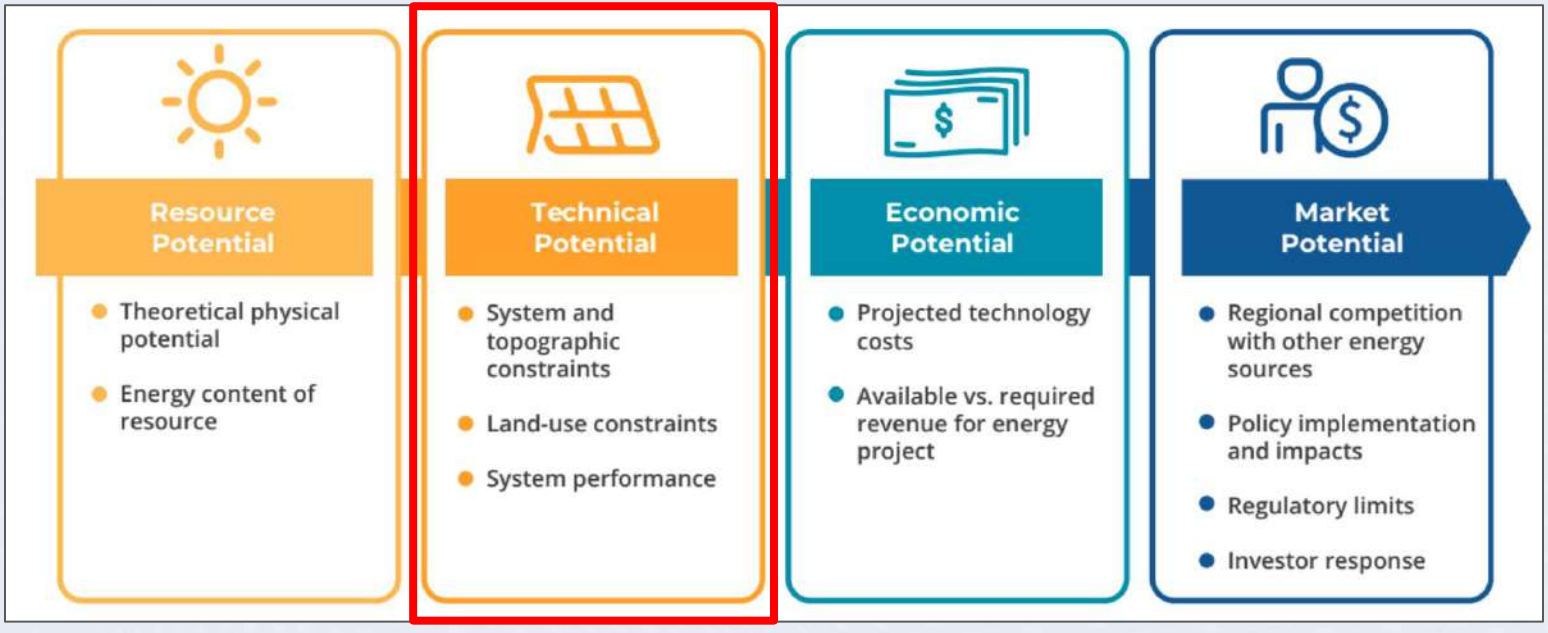
Introduction: Background

1. **Indonesia needs to achieve RE target (23% RE in primary energy mix by 2025; 31% by 2050)**
   - Realization in 2020: **11.5%** → ***need to 2X this number in the next 4 years***
   - RUEN's target for solar PV: **6.5 GW by 2025** (currently being revisited)
   - Incidentally, **solar PV is targeted to represent one-third** (17.6 GW) **of total clean power generation** (48 GW) **by 2035** in the National Energy Grand Strategy (DEN, 2021)
     - ➢ Of which 60/76% (10.7/13.5 GW) is expected to come from utility-scale solar (incl. FPV)
2. **Outdated solar PV technical potential estimate (207 GW, MEMR)**

Purpose of this study:

To provide **an updated geospatial data/assessment** that could be used **to support solar power development** in the country, while at the same time, meet future electricity demand and achieve renewable energy targets.

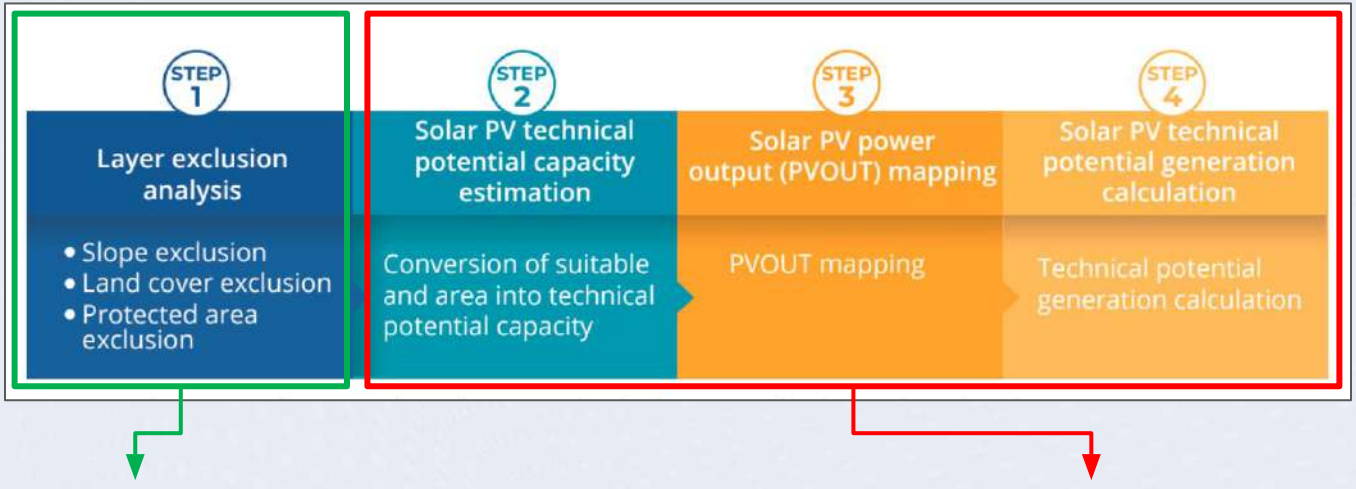
Introduction: Potential Definitions



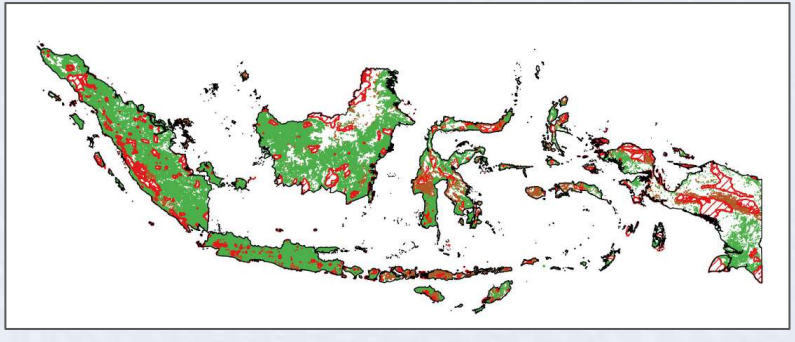
Adapted from NREL (2016)

Technical potential is the achievable *electricity generation capacity* (MW), *generation* (GWh), and *suitable land area* (km^2), given system performance, certain geographic constraints, and technology-specific limitations (NREL, 2016).

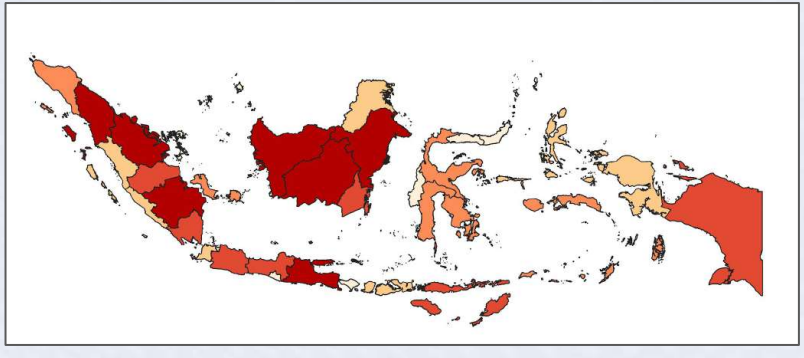
Methods: Overview



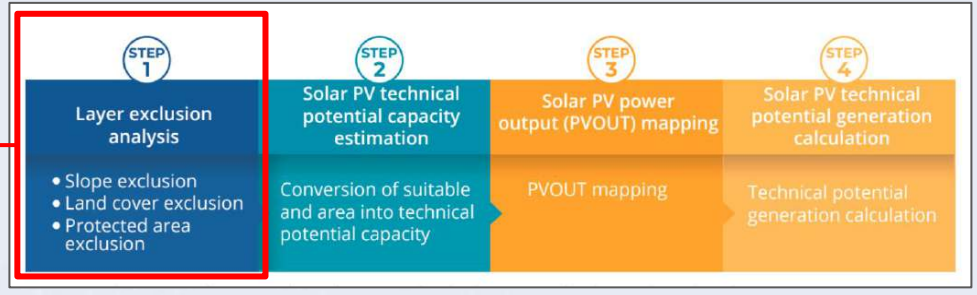
Suitable land area map

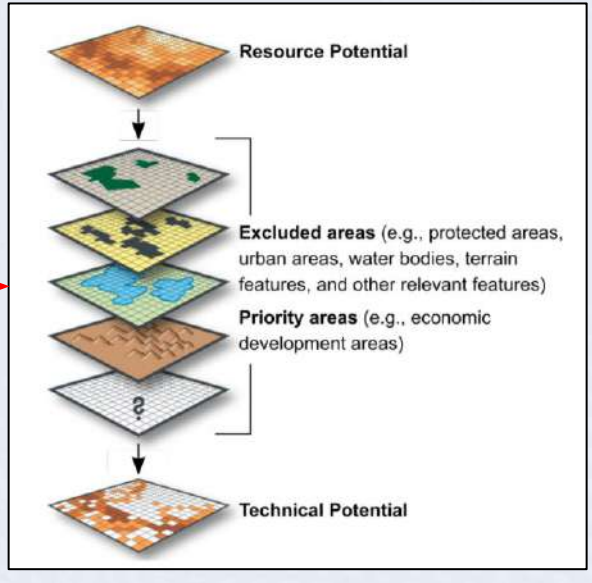


PV generation potential map



Methods: Layer exclusion analysis





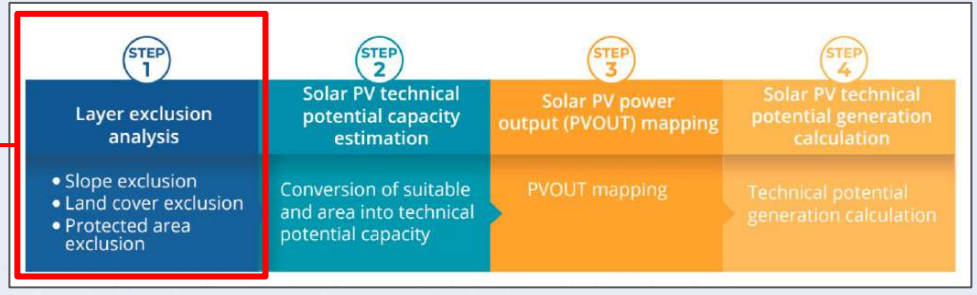
Adapted from NREL (2017)

Slope exclusion:
- **10 º slope exclusion** (or 17.6% in percent slope)
- Using digital elevation model (DEM) layer (BIG, 2018)

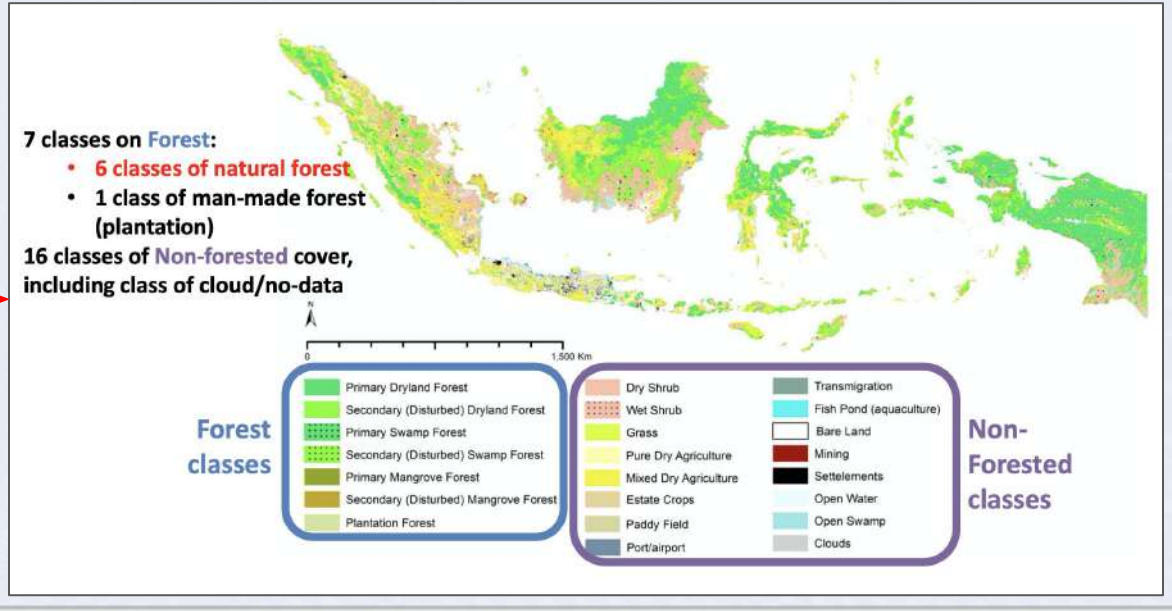
Land cover exclusion:
- Using land cover data (MoEF, 2017)
- Details *in next slide*

Protected areas exclusion:
- Using UNEP's World Database of Protected Areas (2020)
- Areas include:
  - nature reserve (*cagar alam*),
  - wildlife reserve (*suaka margasatwa*),
  - biosphere reserve,
  - national park,
  - heritage sites, etc.

Methods: Land cover exclusion



Land cover exclusion (Using land cover data from MoEF, 2017)



Methods: Land cover exclusion

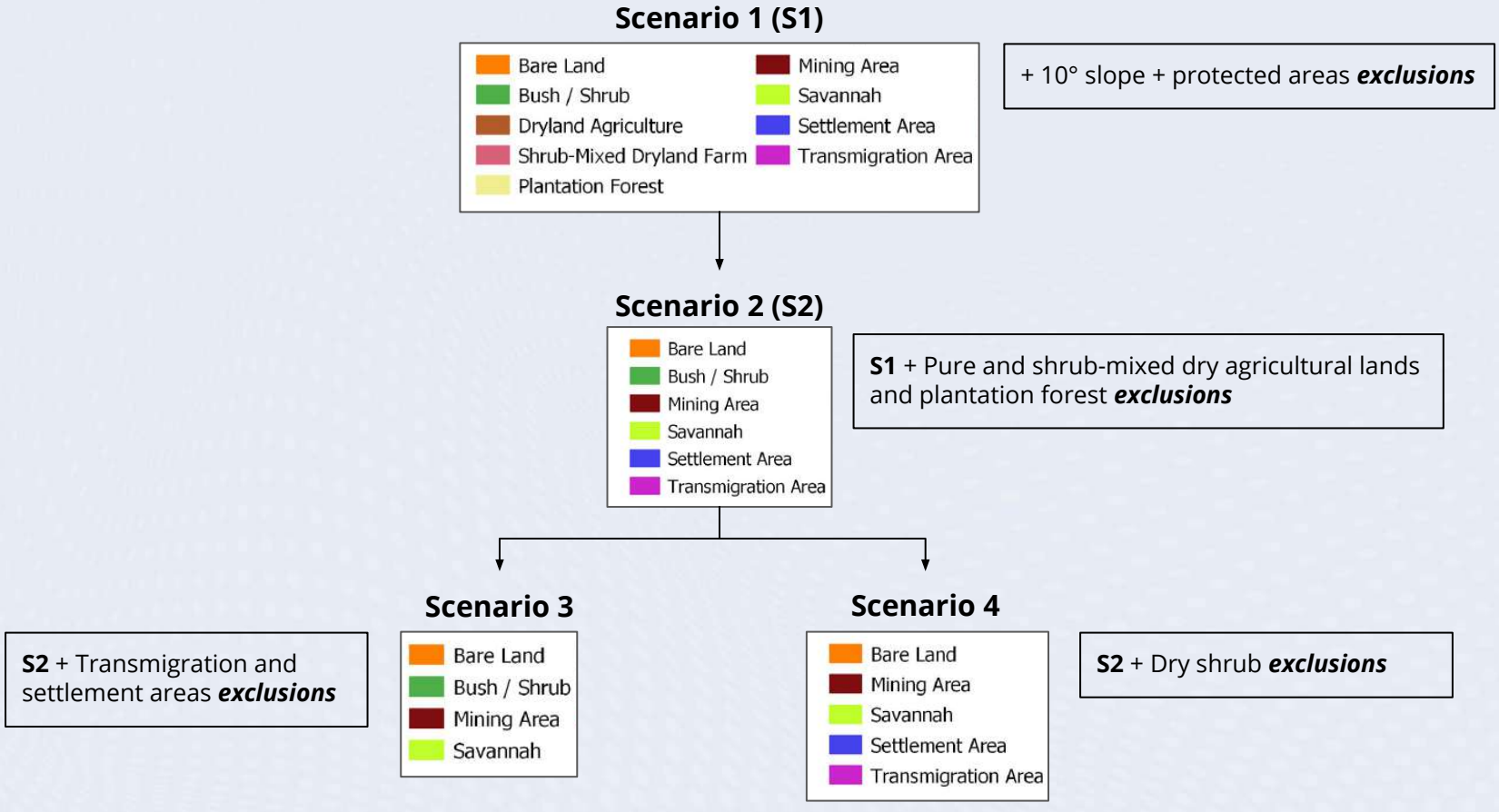
No.	Land cover class (English)	Category[1]	Notes
1	Primary dryland forest	Primary forest	X
2	Primary swamp forest	Primary forest	X
3	Primary mangrove forest	Primary forest	X
4	Secondary dryland forest	Secondary forest	X
5	Secondary swamp forest	Secondary forest	X
6	Secondary mangrove forest	Secondary forest	X
7	**Plantation forest** (man-made)	Plantation forest	✓
8	**Dry shrub**	Grassland	✓
9	**Savannah**	Grassland	✓
10	**Pure dry agricultural land**	Cropland	✓
11	**Shrub-mixed dry agricultural land**	Cropland	✓
12	Estate crops (plantation)	Cropland	X
13	Paddy field	Cropland	X
14	**Bare land**	Other land	✓
15	Fish pond (aquaculture)	Other land	X
16	Airport/harbour	Other land	X
17	**Mining**	Other land	✓
18	**Transmigration**	Settlements	✓
19	**Settlements**	Settlements	✓
20	Swamp shrub	Wetland	X
21	Open swamp	Wetland	X
22	Open water	Bodies of water	X
23	Clouds (no data)	No data	X

Nine selected "suitable" land cover:

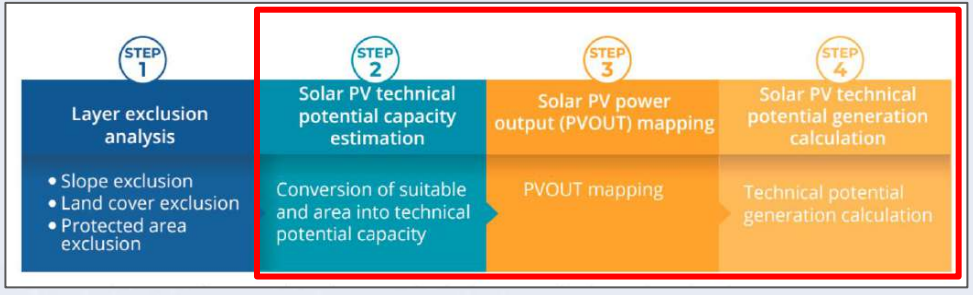
Plantation forest and **agricultural lands** are included (for Scenario 1) because the land are acquirable as previously seen in the **3 x 7 MWp ground-mounted solar projects** in **Lombok**, East Nusa Tenggara and **21 MWp** ground-mounted solar farm in **Likupang**, North Sulawesi (ADB, 2018a, 2018b)

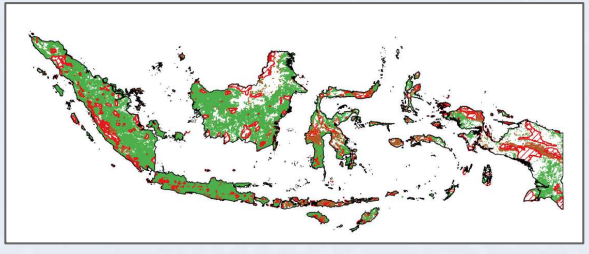
[1]Note: further reclassification by World Resource Institute (Global Forest Watch, 2020)

Methods: Land cover exclusion scenarios



Methods: Technical potential (capacity and generation) calculations





Suitable area map

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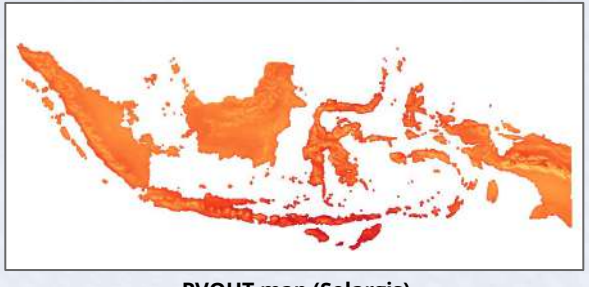
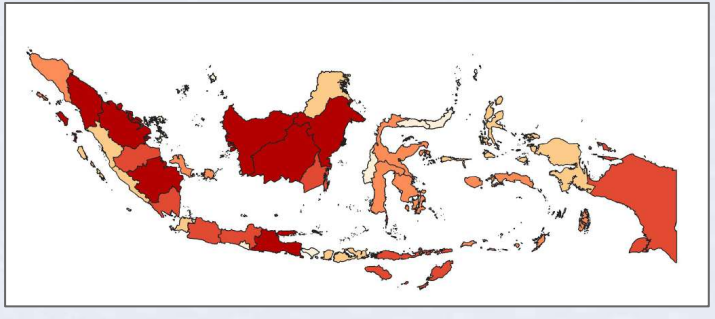


PVOUT map (Solargis)



Technical potential capacity *(GWp)* = ***Land Area*** *(km²)* x ***Power Density*** *(GWp/km²)*

Technical potential generation *(TWh/year)* = ***Technical potential capacity*** *(GWp)* x ***PVOUT*** *(GWh/GWp)/year*

Note: a power density of 0.41 MWp/ha (0.041 GWp/km²) was used in this work

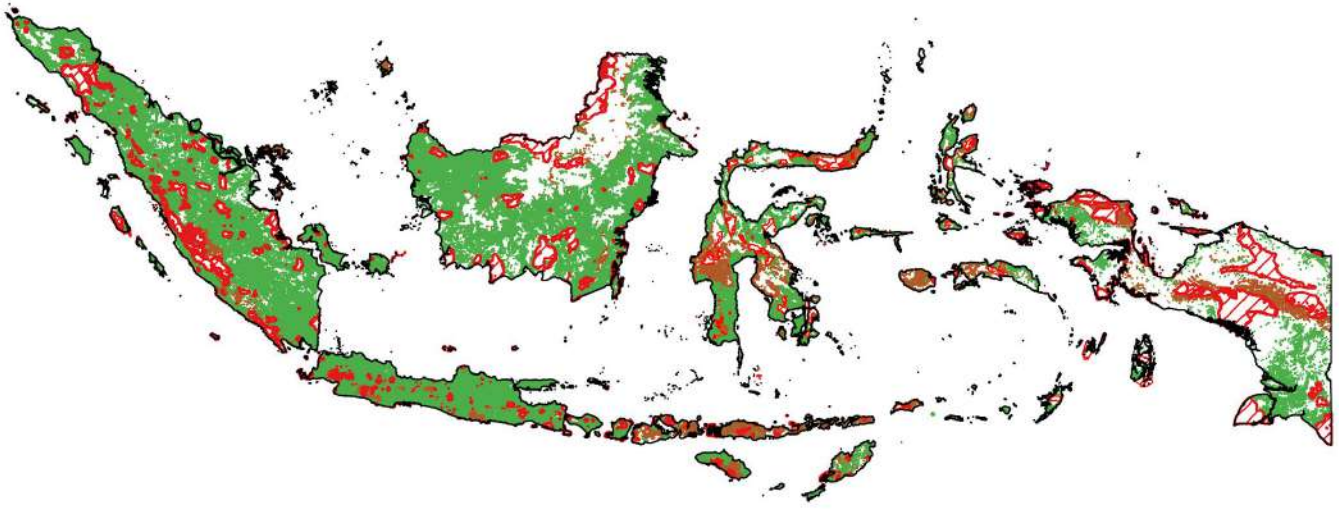
Results: Summary

Table 4. Summary of Indonesia's solar PV technical potential assessment

Scenarios:	Suitable area (km^2) (*% of Indonesia's total land mass*)	Solar PV Technical Potential		
		Capacity (GWp)	Generation (TWh/year)	
Scenario 1 (S1): Base exclusions (protected areas, forested areas, water bodies, wetland areas, airports and seaports) + slope exclusion (>10°)	484,455 (*24.43%*)	19,835	26,972	**95x**
Scenario 2 (S2): S1 + agricultural lands (both pure and shrub-mixed) and plantation forest areas exclusions	187,806 (*9.85%*)	7,700	10,508	**37x**
Scenario 3 (S3): S2 + transmigration and settlements areas exclusions	153,915 (*8.07%*)	6,310	8,541	**30x**
Scenario 4 (S4): S2 + dry shrub exclusion	82,847 (*4.34%*)	3,397	4,705	**16x**

Notes: Scenario 1 includes dry shrub, savanna, bare land, mining, transmigration, settlements, plantation forests, pure dry and mixed agricultural lands; **Scenario 2** excludes plantation forests, pure dry and mixed agricultural lands from Scenario 1; **Scenario 3** excludes transmigration and settlements from Scenario 2; and **Scenario 4** excludes dry shrub from Scenario 2;

Results: Suitable area map (Scenario 1)



Indonesia's solar PV suitable area map (Scenario 1)

- Suitable Land
- Suitable Land Use with Unsuitable Slope
- Restricted Land Use
- Protected Areas

% Suitable area by land cover type (not shown for image clarity):

Bare Land	— 6%	Mining Area	— 1%
Bush / Shrub	— 23%	Savannah	— 3%
Dryland Agriculture	— 18%	Settlement Area	— 7%
Shrub-Mixed Dryland Farm	— 33%	Transmigration Area	— 1%
Plantation Forest	— 8%		

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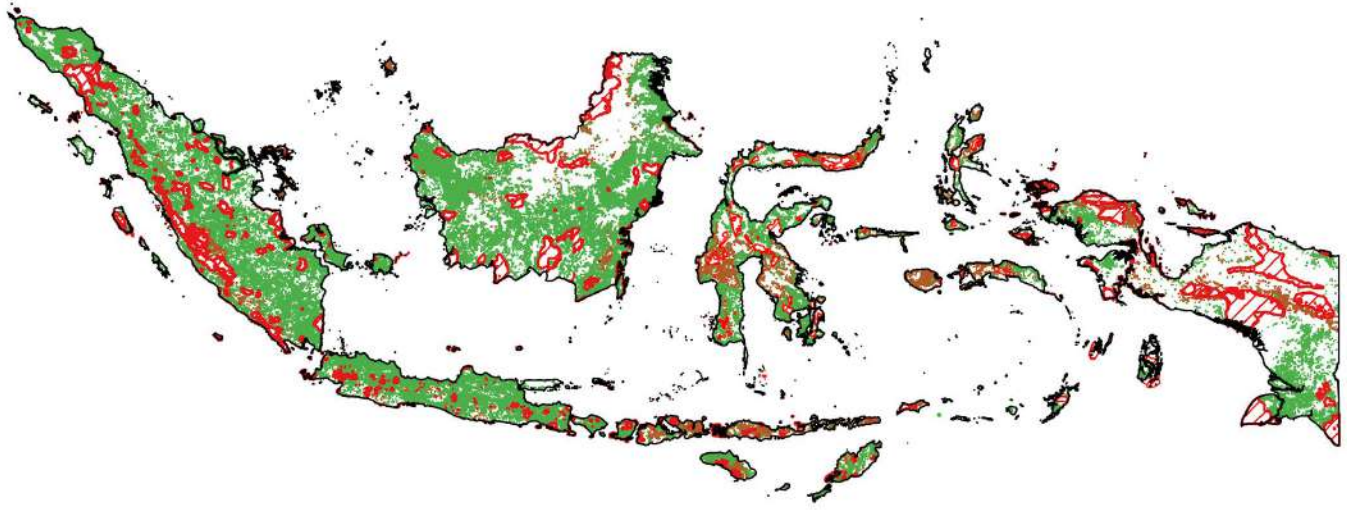
Results: Suitable area map (Scenario 2)



Indonesia's solar PV suitable area map (Scenario 2)

- Suitable Land
- Suitable Land Use with Unsuitable Slope
- Restricted Land Use
- Protected Areas

% Suitable area by land cover type (not shown for image clarity):

Bare Land	— **14.5%**
Bush / Shrub	— **55.8%**
Mining Area	— **3.4%**
Savannah	— **8.1%**
Settlement Area	— **16.8%**
Transmigration Area	— **1.4%**

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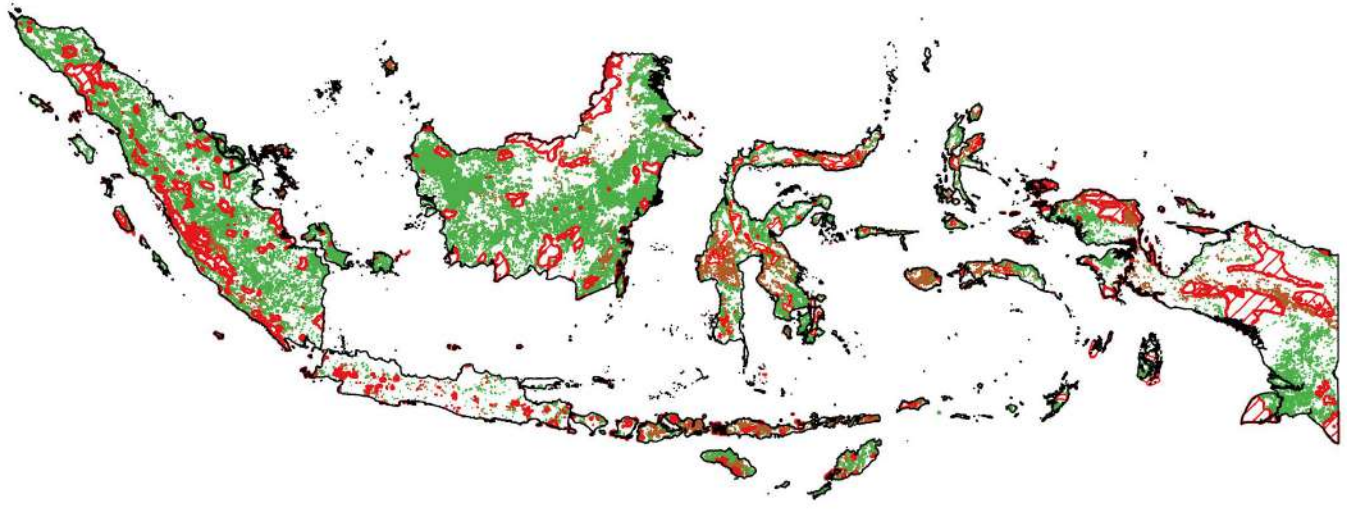
Results: Suitable area map (Scenario 3)



Indonesia's solar PV suitable area map (Scenario 3)

- Suitable Land
- Suitable Land Use with Unsuitable Slope
- Restricted Land Use
- Protected Areas

% Suitable area by land cover type (not shown for image clarity):

- Bare Land — **17.7%**
- Bush / Shrub — **68.3%**
- Mining Area — **4.2%**
- Savannah — **9.9%**

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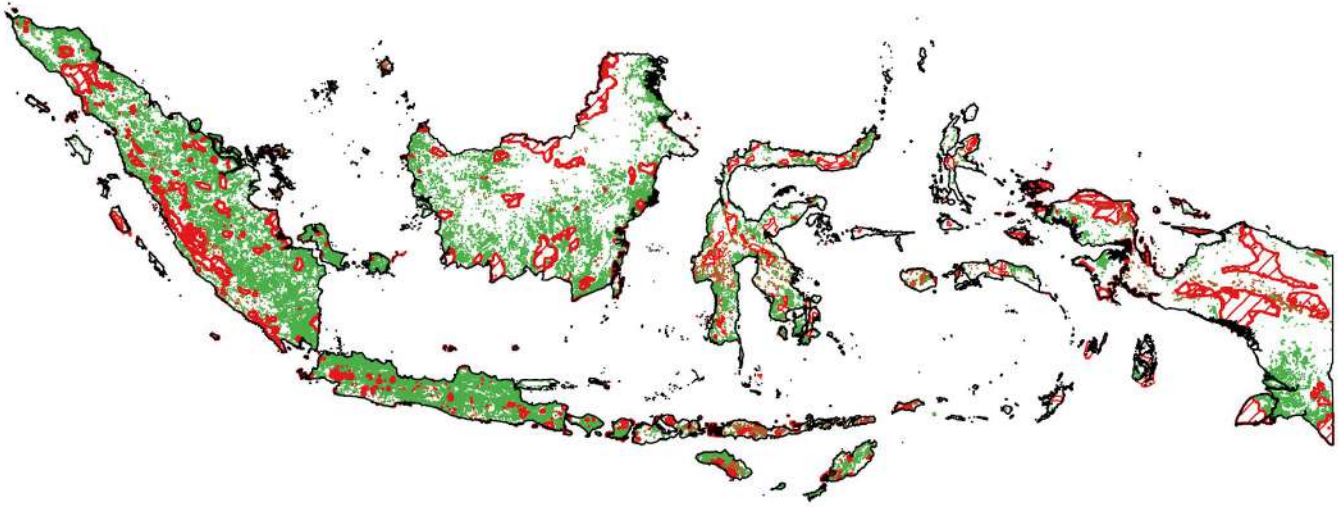
Results: Suitable area map (Scenario 4)



Indonesia's solar PV suitable area map (Scenario 4)

- Suitable Land
- Suitable Land Use with Unsuitable Slope
- Restricted Land Use
- Protected Areas

% Suitable area by land cover type (not shown for image clarity):

Bare Land	— **32.8%**
Mining Area	— **7.8%**
Savannah	— **18.3%**
Settlement Area	— **38.1%**
Transmigration Area	— **3.1%**

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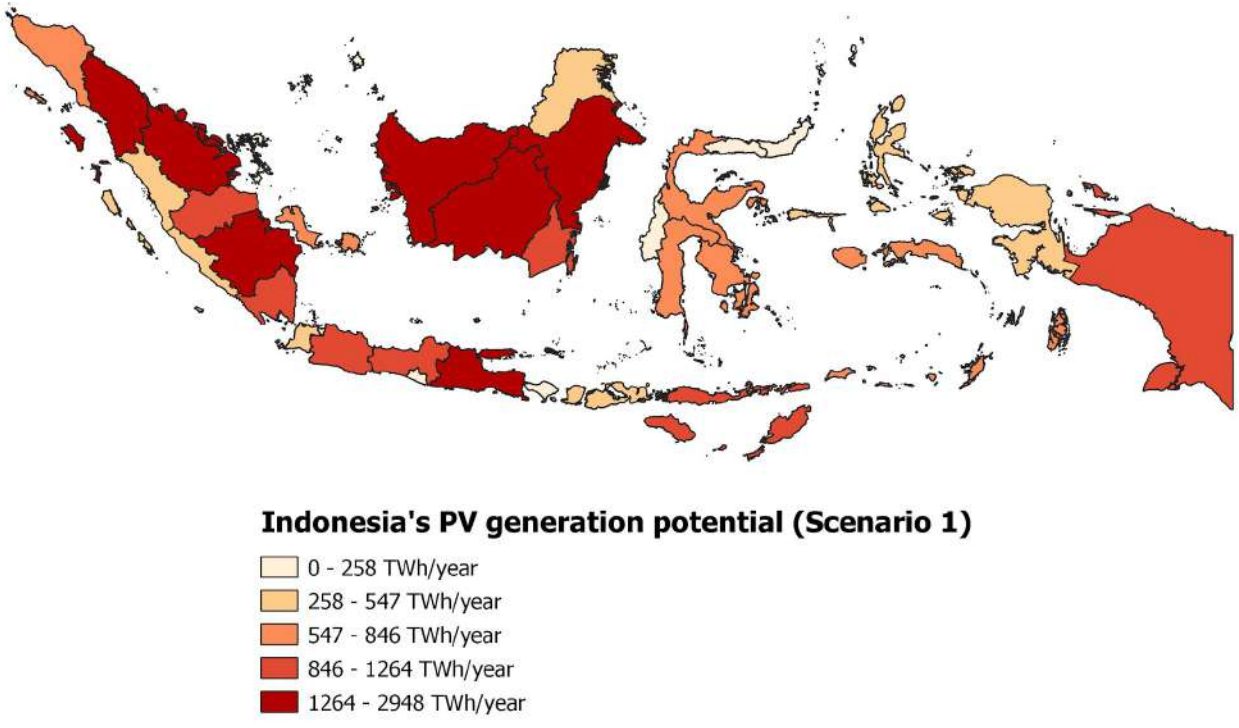
Results: PV generation potential map (Scenario 1)



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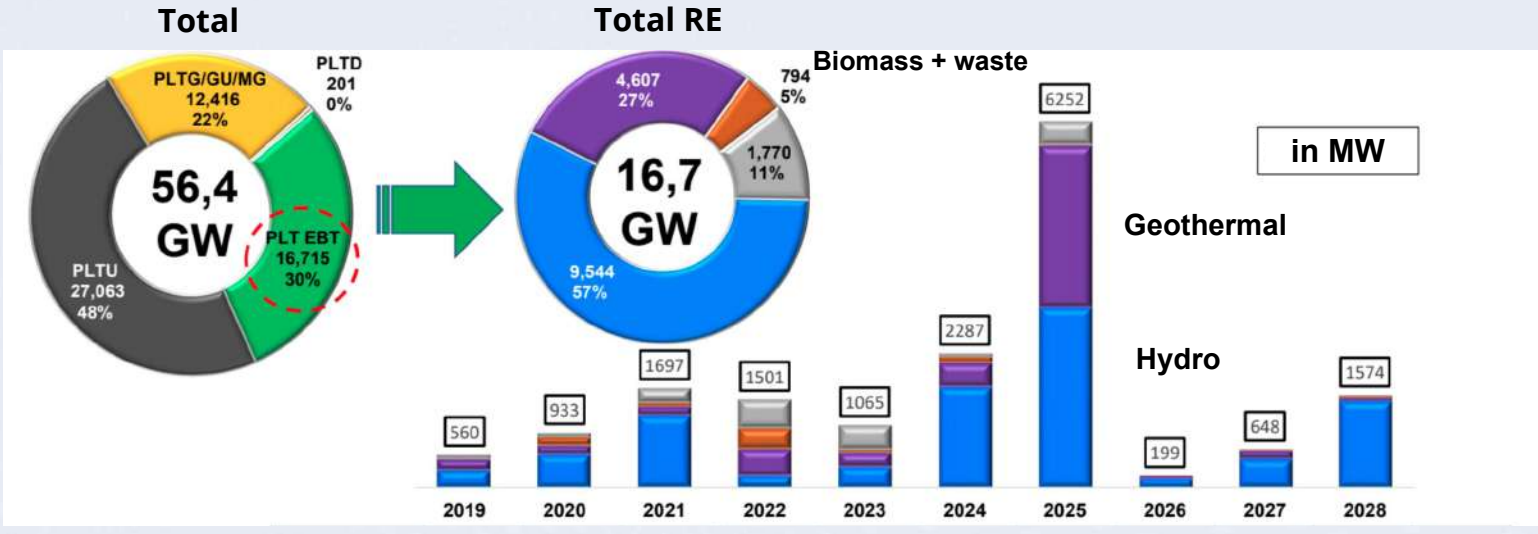
Discussion: National electricity demand

Planned power generation capacity addition, 2019–2028 (pre-COVID)



Source: Directorate-General of Electricity (DJK), MEMR, PLN (RUPTL 2019)

- **Solar PV only accounts for 1.6%** (908 MW) **of total planned generation capacity in the 2019's RUPTL**
- **In the upcoming RUPTL (2021–2030), total planned capacity is cut by 15.5 GW** to 40.9 GW
- Electricity demand growth projection (10-year average): from **6.4%** to **4.9%**
- **Solar PV, wind, and waste-to-energy together will account for 3.7 GW** in the upcoming RUPTL (no details yet on specific ratio for solar PV) (Umah, 2021)

Discussion: Case study in Bali

Bali's power system overview (2019, pre-COVID)

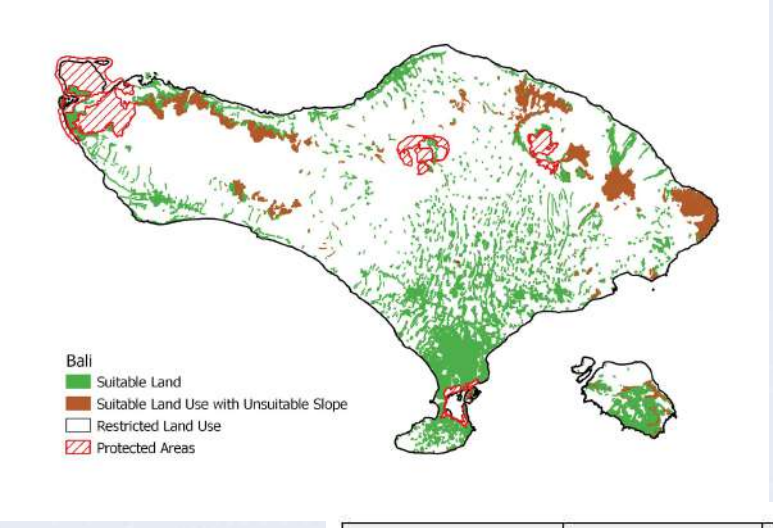
Source: PLN's electricity supply business plan (RUPTL) 2019–2028

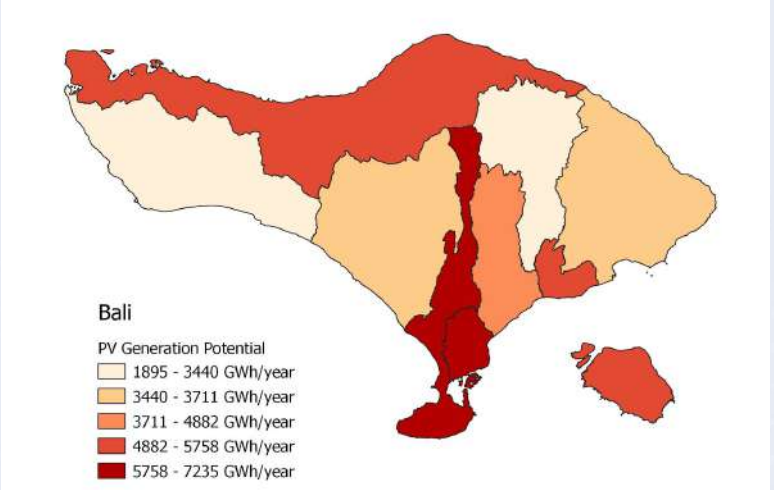
- **Current peak demand:** 980 MW (Jan 2020) (PLN Bali, 2020)
  - 10-year growth projection (pre-COVID): 6.31%
  - Electricity sales (2019): 5,706.72 GWh
- **Current power supply:**
  - Inland power generation: 1,042 MW
  - Submarine cable transmission (Java): 420 MW
- **Planned additional capacity from solar PV:** 100 MW
  - 2 x 25 MW (ongoing, waiting for PPA)

➢ **Calculated technical potential (Scenario 2): 26.4 GWp**

***Note*:** Electricity demand projection **is still based on pre-COVID** pandemic (there will be adjustments in the upcoming RUPTL)

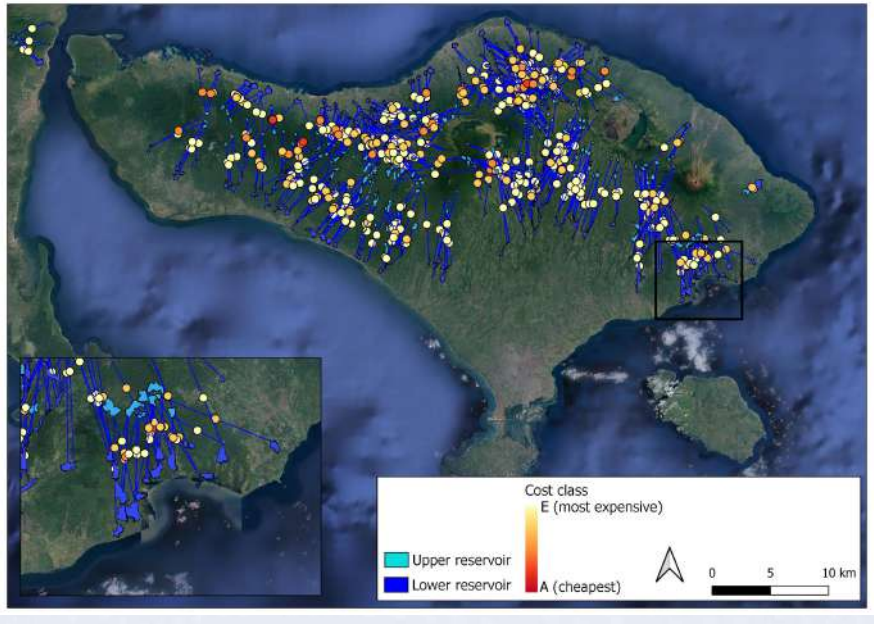
Discussion: Case study in Bali





Regency/city	Suitable Land (km^2)	Potential Capacity (GWp)	Potential Generation (GWh/year)
Badung	111.88	4.59	7,234.73
Bangli	33.03	1.35	1,894.88
Buleleng	86.53	3.55	5,418.47
Gianyar	70.15	2.88	4,361.63
Jembrana	53.21	2.18	3,295.04
Karangasem	56.96	2.34	3,536.67
Klungkung	78.05	3.20	5,012.64
Kota Denpasar	94.13	3.86	6,266.45
Tabanan	59.91	2.46	3,548.97
Total	**643.85**	**26.40**	**40,569.47**

Discussion: Case study in Bali



Source: Stocks et al., ANU (2021); IESR analysis

Cost class	Total number of PHS	Energy (GWh)	Storage time (h)	Total energy (GWh)
A	0	2	6	0.0
	0	5	6	0.0
	1	5	18	0.3
	0	15	6	0.0
B	0	2	6	0.0
	1	5	6	0.8
	3	5	18	0.8
	4	15	6	10.0
C	10	2	6	3.3
	31	5	6	25.8
	29	5	18	8.1
	21	15	6	52.5
D	54	2	6	18.0
	51	5	6	42.5
	65	5	18	18.1
	50	15	6	125.0
E	74	2	6	24.7
	73	5	6	60.8
	78	5	18	21.7
	59	15	6	147.5
Total energy from all cost-classes and storage (GWh)				**559.9**

Case study in Sumba Island, East Nusa Tenggara

Sumba's power system overview (2019, pre-COVID)

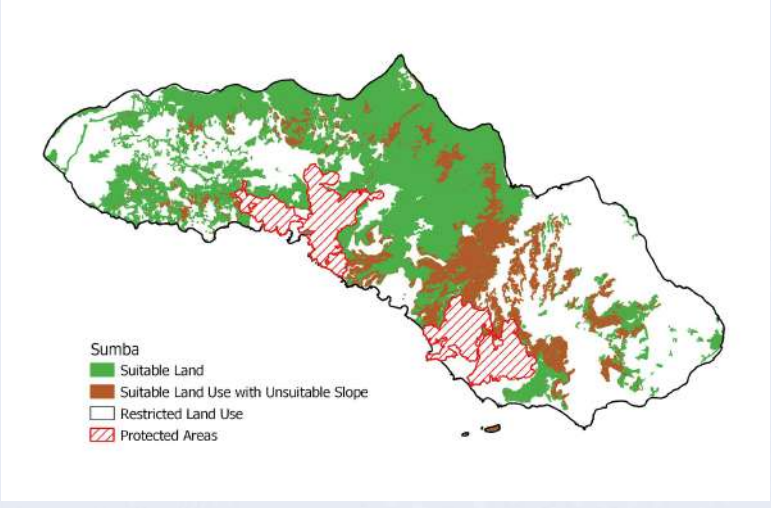
Source: PLN's electricity supply business plan (RUPTL) 2019–2028

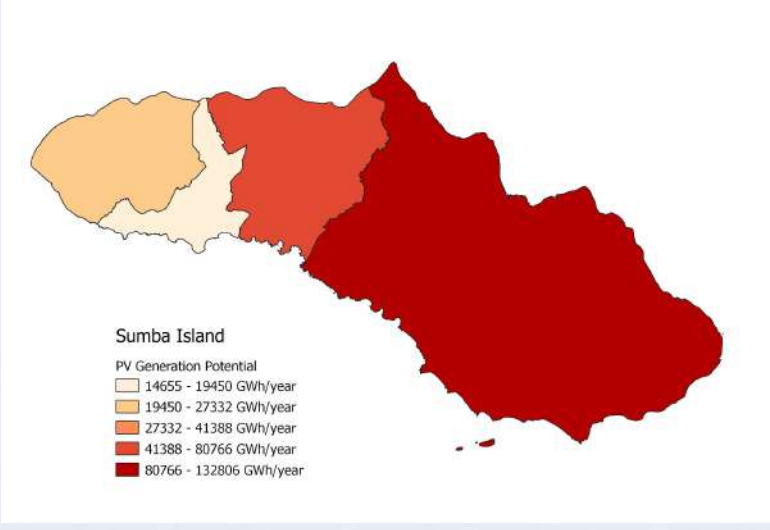
- **Current peak demand:** 213 MW (entire East Nusa Tenggara)
  - 10-year growth projection (pre-COVID): 8.15%
  - Electricity sales (2019): 999.5 GWh
- **Current power supply (in Sumba):**
  - 9 units of diesel generators: 11 MW
  - 4 units of micro hydro power plants: 3 MW
  - 1 unit of solar PV power plant: 0.2 MW
- **Planned additional capacity from solar PV**: 3.8 MW
  - Sumba solar barn initiative "*lumbung surya*": 2 GW

➢ **Calculated technical potential (Scenario 2): 133 GWp**

***Note*:** Electricity demand projection **is still based on pre-COVID** pandemic (there will be adjustments in the upcoming RUPTL)

Case study in Sumba Island, East Nusa Tenggara





Regency	Suitable Land (km^2)	Potential Capacity (GWp)	Potential Generation (GWh/year)
Sumba Barat	227.90	9.34	14,655.32
Sumba Barat Daya	356.25	14.61	22,646.70
Sumba Tengah	686.77	28.16	46,073.12
Sumba Timur	1,973.82	80.93	132,805.65
Total	**3,244.75**	**133.03**	**216,180.79**

Concluding Remarks

- **Indonesia's solar PV technical potential capacity** is found to range between **3,396 GWp** up to **19,835 GWp**, with generation potential of **4,705 – 26,791 TWh/year**, by taking up **4.34% to 24.43% of the total land mass** (depending on the scenario).
- Our results also show that **Indonesia's utility-scale solar PV potential is well above** (**16X to 95X**) **the current national official estimate**, that is 207 GW.

Recommendations:

- **The government could update their nationwide solar PV technical potential figures**, as to reflect on the more detailed potential for solar power development in Indonesia
- **Local government and respective PLN's regional office could identify prospective locations for solar PV projects,** using the findings in this study as an entry point to a more detailed planning on the ground. Assessment should include current and projection of electricity supply and demand in the area, grid study, financing needs, as well as related policies and incentives.
- **Further technical assessments** can be conducted, particularly to **zoom in specific locations at cities/regencies level** and even smaller, not only for utility/large-scale solar, but also for floating solar and rooftop solar.

Backup slides (skipped)

Table 5. Summary of solar PV technical potential in Indonesia (Scenario 1)

No	Province	Suitable Area (km^2)	Capacity Potential (GWp)	Generation Potential (TWh/year)
1	Aceh	10,657	437	603
2	Sumatera Utara	27,625	1,133	1,509
3	Sumatera Barat	9,809	402	540
4	Riau	29,221	1,198	1,557
5	Jambi	22,574	926	1,198
6	Sumatera Selatan	27,213	1,116	1,495
7	Bengkulu	7,918	325	453
8	Lampung	16,464	675	909
9	Kepulauan Bangka Belitung	11,269	462	604
10	Kepulauan Riau	1,156	47	63
11	DKI Jakarta	593	24	33
12	Jawa Barat	16,746	687	946
13	Jawa Tengah	16,325	669	960
14	DI Yogyakarta	2,296	94	139
15	Jawa Timur	22,168	909	1,362
16	Banten	4,872	200	266
17	Bali	3,453	142	0.21
18	Nusa Tenggara Barat	4,759	195	309
19	Nusa Tenggara Timur	15,424	632	1,025
20	Kalimantan Barat	53,732	2,203	2,948
21	Kalimantan Tengah	34,435	1,412	1,877
22	Kalimantan Selatan	15,843	650	851
23	Kalimantan Timur	39,205	1,607	2,096
24	Kalimantan Utara	5,588	229	311
25	Sulawesi Utara	4,168	169	247
26	Sulawesi Tengah	10,626	430	619
27	Sulawesi Selatan	13,798	559	826
28	Sulawesi Tenggara	11,081	452	647
29	Gorontalo	2,376	96	146
30	Sulawesi Barat	2,859	114	168
31	Maluku	9,823	399	573
32	Maluku Utara	7,899	322	464
33	Papua Barat	4,874	200	274
34	Papua	17,607	722	955
	Total	**484,455**	**19,835**	**26,972**

Note: The provinces are arranged based on official numbering by the Ministry of Home Affairs (MoHA, 2017) (see Appendix B for more details).

Table 6. Summary of solar PV technical potential in Indonesia (Scenario 2)

No	Province	Suitable Area (km^2)	Capacity Potential (GWp)	Generation Potential (TWh/year)
1	Aceh	5,293	217	300
2	Sumatera Utara	5,786	237	317
3	Sumatera Barat	2,059	84	113
4	Riau	7,267	298	386
5	Jambi	6,744	276	358
6	Sumatera Selatan	10,760	441	589
7	Bengkulu	1,570	64	91
8	Lampung	3,495	143	194
9	Kepulauan Bangka Belitung	5,343	219	287
10	Kepulauan Riau	622	25	34
11	DKI Jakarta	571	23	32
12	Jawa Barat	3,453	142	199
13	Jawa Tengah	4,699	193	284
14	DI Yogyakarta	680	28	41
15	Jawa Timur	4,876	200	306
16	Banten	948	39	52
17	Bali	644	26	41
18	Nusa Tenggara Barat	1,275	52	83
19	Nusa Tenggara Timur	8,258	339	552
20	Kalimantan Barat	24,360	999	1,343
21	Kalimantan Tengah	14,770	606	805
22	Kalimantan Selatan	5,116	210	274
23	Kalimantan Timur	27,330	1,121	1,466
24	Kalimantan Utara	3,481	143	194
25	Sulawesi Utara	507	21	30
26	Sulawesi Tengah	4,117	169	238
27	Sulawesi Selatan	2,588	106	153
28	Sulawesi Tenggara	5,023	206	294
29	Gorontalo	407	17	25
30	Sulawesi Barat	678	28	40
31	Maluku	4,960	203	289
32	Maluku Utara	2,069	85	120
33	Papua Barat	3,924	161	220
34	Papua	14,133	579	759
	Total	**187,806**	**7,700**	**10,508**

Note: The provinces are arranged based on official numbering by the Ministry of Home Affairs (MoHA, 2017) (see Appendix B for more details).

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Table 7. Summary of solar PV technical potential in Indonesia (Scenario 3)

No	Province	Suitable Area (km^2)	Capacity Potential (GWp)	Generation Potential (TWh/year)
1	Aceh	3,911	160	221
2	Sumatera Utara	4,980	204	273
3	Sumatera Barat	1,674	69	91
4	Riau	6,094	250	323
5	Jambi	5,627	231	299
6	Sumatera Selatan	8,490	348	464
7	Bengkulu	1,293	53	75
8	Lampung	879	36	49
9	Kepulauan Bangka Belitung	4,998	205	269
10	Kepulauan Riau	466	19	25
11	DKI Jakarta	0.67	0.03	0.04
12	Jawa Barat	93	4	5
13	Jawa Tengah	83	3	5
14	DI Yogyakarta	6.32	0.26	0.36
15	Jawa Timur	437	18	27
16	Banten	61	3	3
17	Bali	161	7	10
18	Nusa Tenggara Barat	896	37	59
19	Nusa Tenggara Timur	7,398	303	495
20	Kalimantan Barat	23,748	974	1,309
21	Kalimantan Tengah	13,958	572	760
22	Kalimantan Selatan	4,513	185	242
23	Kalimantan Timur	26,497	1,086	1,422
24	Kalimantan Utara	3,235	133	180
25	Sulawesi Utara	293	12	17
26	Sulawesi Tengah	3,659	150	211
27	Sulawesi Selatan	1,908	78	111
28	Sulawesi Tenggara	4,665	191	273
29	Gorontalo	261	11	16
30	Sulawesi Barat	470	19	27
31	Maluku	4,612	189	269
32	Maluku Utara	1,900	78	110
33	Papua Barat	3,432	141	192
34	Papua	13,213	542	707
	Total	**153,915**	**6,310**	**8,541**

Note: The provinces are arranged based on official numbering by the Ministry of Home Affairs (MoHA, 2017) (see Appendix B for more details).

Table 8. Summary of solar PV technical potential in Indonesia (Scenario 4)

No	Province	Suitable Area (km^2)	Capacity Potential (GWp)	Generation Potential (TWh/year)
1	Aceh	2,094	86	120
2	Sumatera Utara	2,861	117	158
3	Sumatera Barat	873	36	49
4	Riau	7,059	289	375
5	Jambi	3,306	136	175
6	Sumatera Selatan	7,546	309	412
7	Bengkulu	371	15	22
8	Lampung	2,837	116	157
9	Kepulauan Bangka Belitung	2,546	104	137
10	Kepulauan Riau	310	13	17
11	DKI Jakarta	571	23	32
12	Jawa Barat	3,433	141	198
13	Jawa Tengah	4,637	190	280
14	DI Yogyakarta	677	28	41
15	Jawa Timur	4,607	189	289
16	Banten	935	38	52
17	Bali	507	21	32
18	Nusa Tenggara Barat	445	18	29
19	Nusa Tenggara Timur	6,203	254	416
20	Kalimantan Barat	3,421	140	188
21	Kalimantan Tengah	4,911	201	270
22	Kalimantan Selatan	2,158	88	116
23	Kalimantan Timur	3,660	150	194
24	Kalimantan Utara	933	38	52
25	Sulawesi Utara	263	11	16
26	Sulawesi Tengah	1,026	42	60
27	Sulawesi Selatan	1,033	42	62
28	Sulawesi Tenggara	1,781	73	105
29	Gorontalo	150	6	9
30	Sulawesi Barat	315	13	19
31	Maluku	1,544	63	90
32	Maluku Utara	295	12	17
33	Papua Barat	1,642	67	91
34	Papua	7,897	324	427
	Total	**82,847**	**3,397**	**4,705**

Note: The provinces are arranged based on official numbering by the Ministry of Home Affairs (MoHA, 2017) (see Appendix B for more details).

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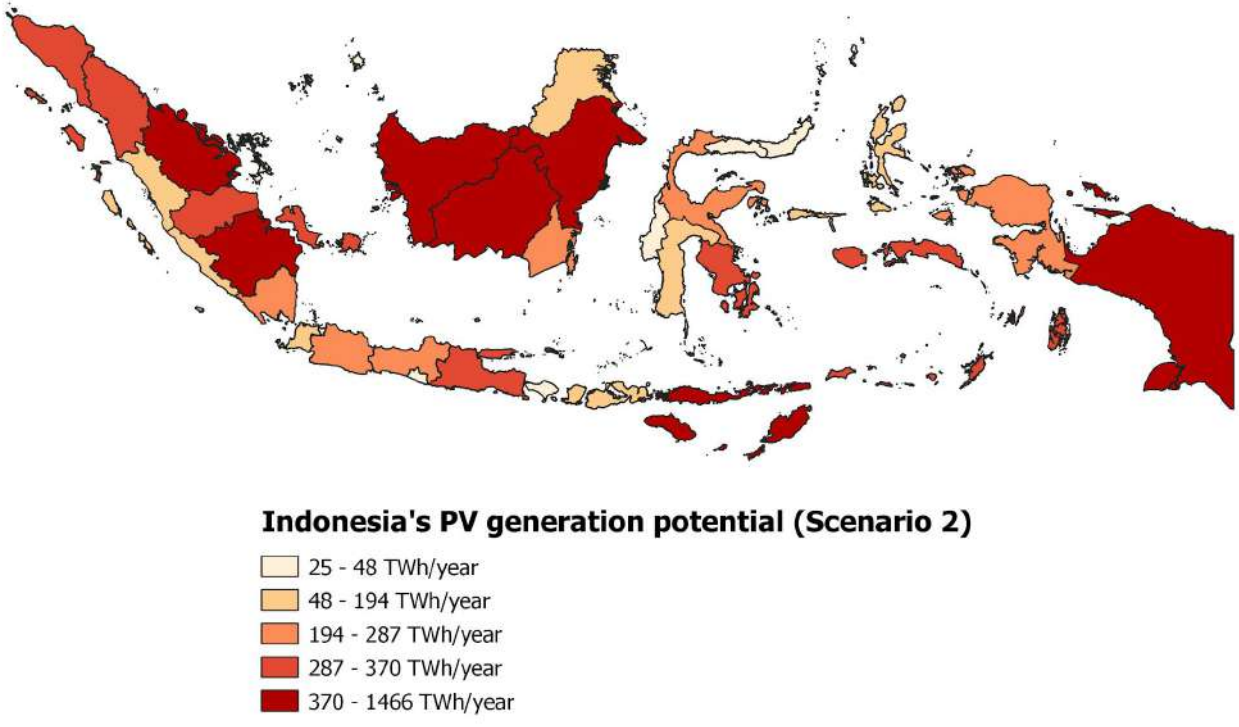

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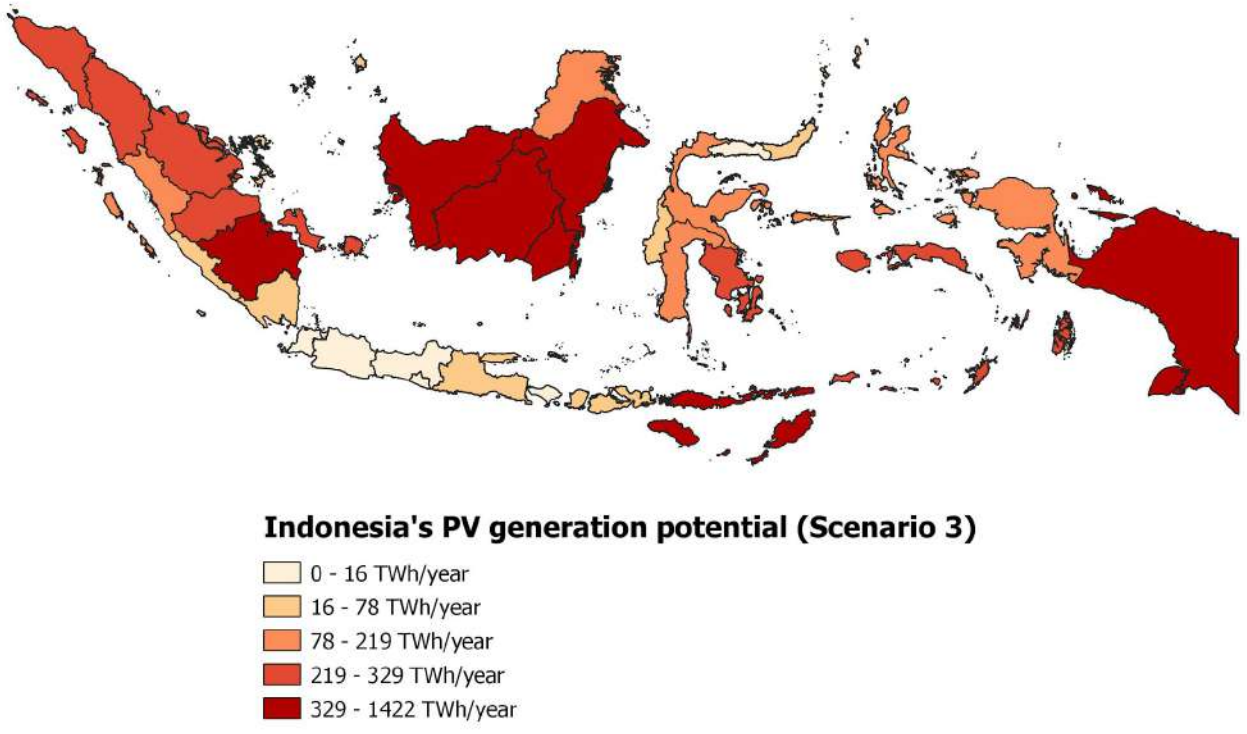

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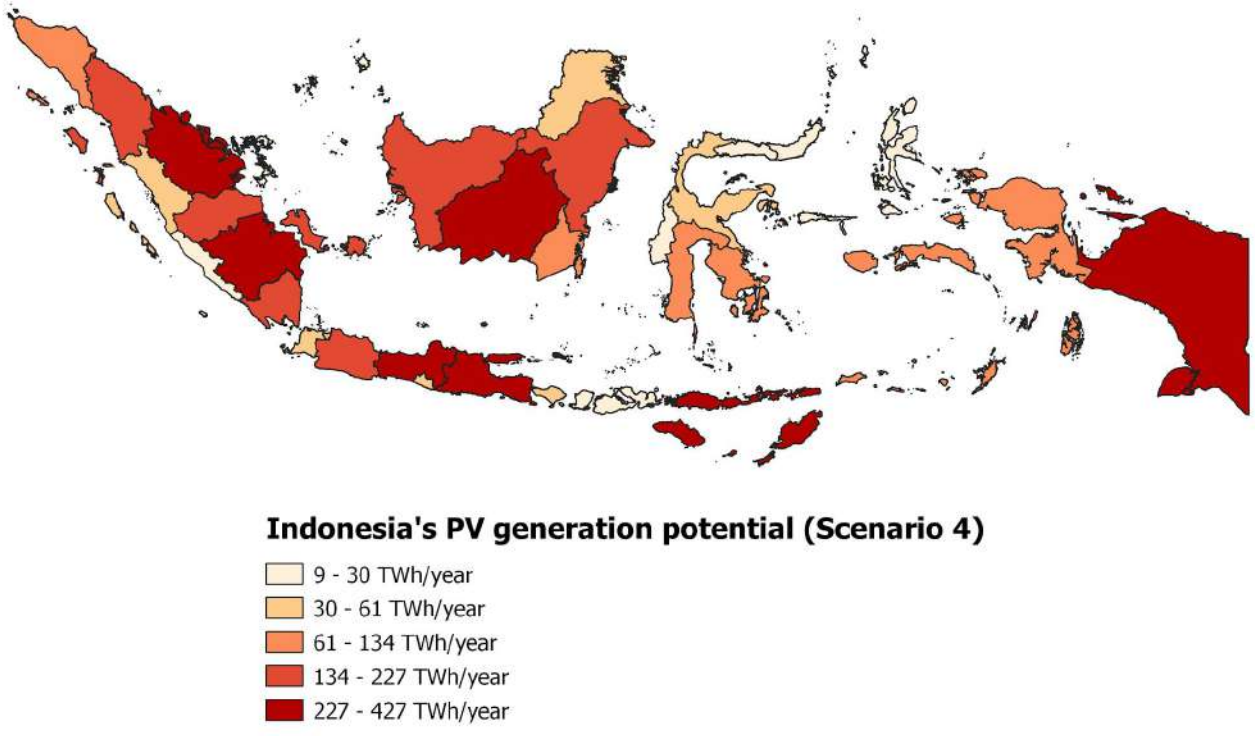

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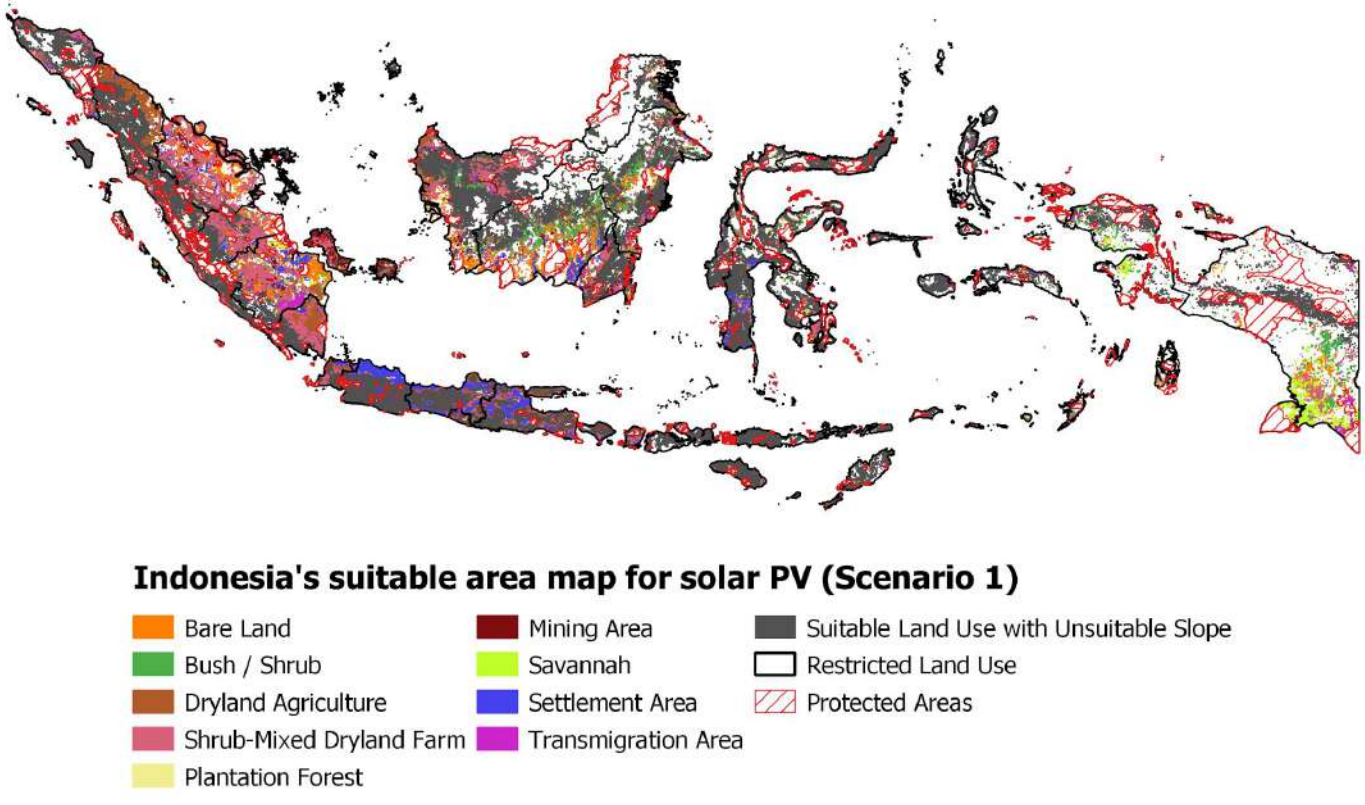

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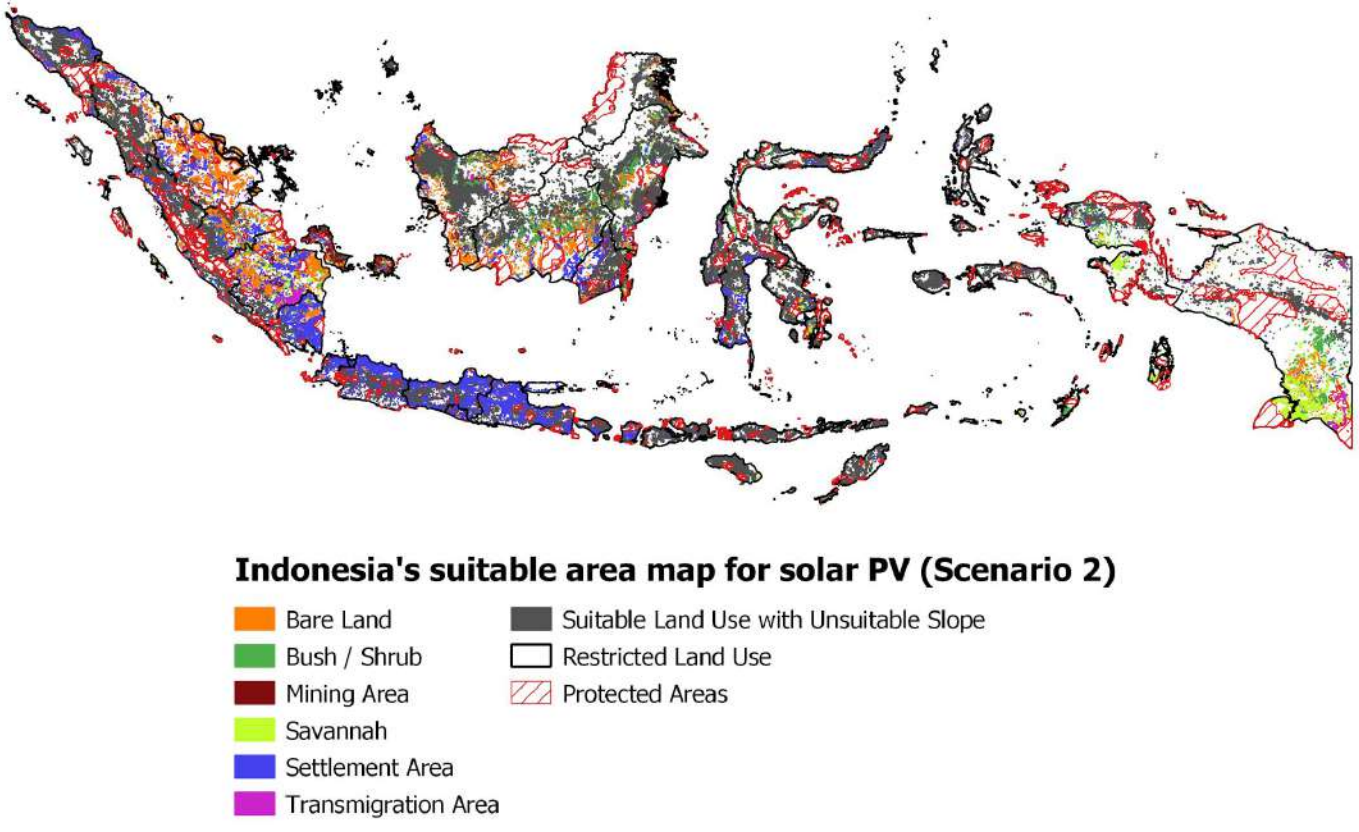

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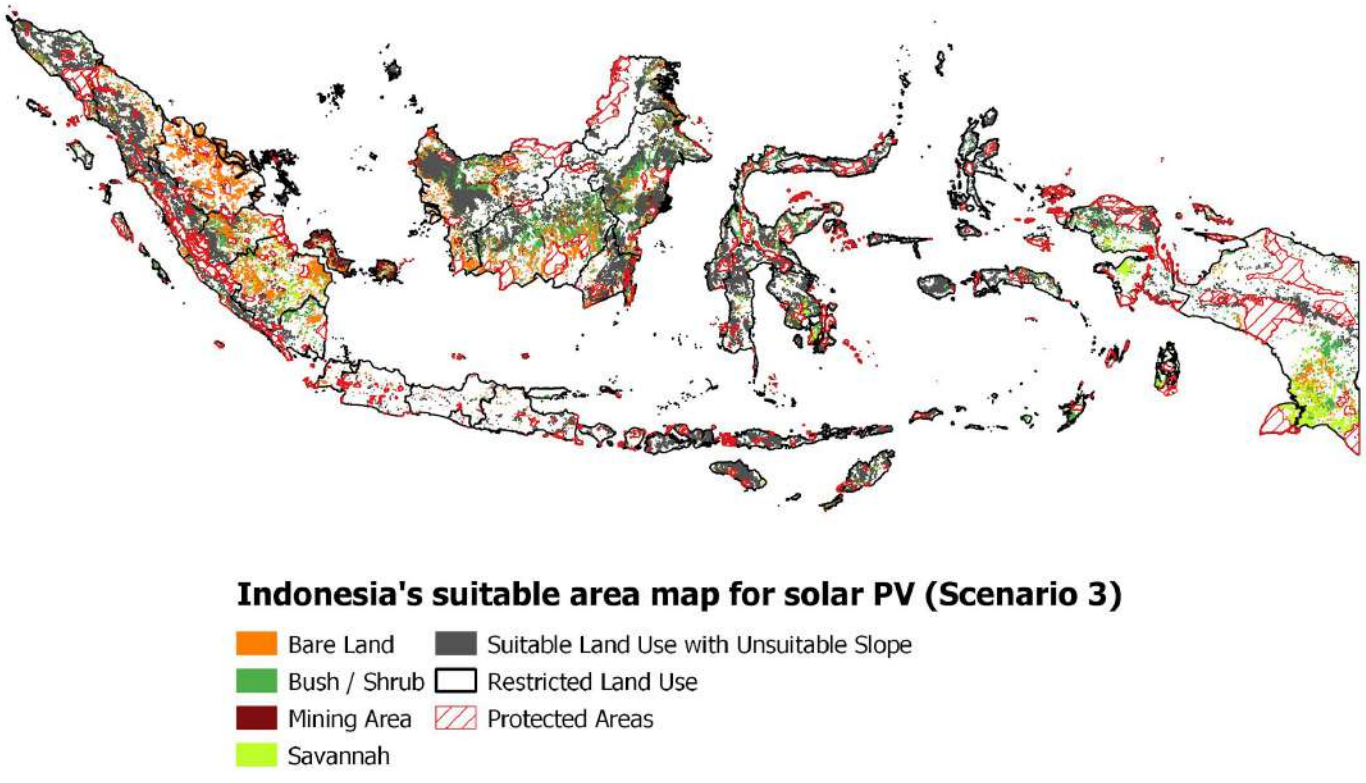

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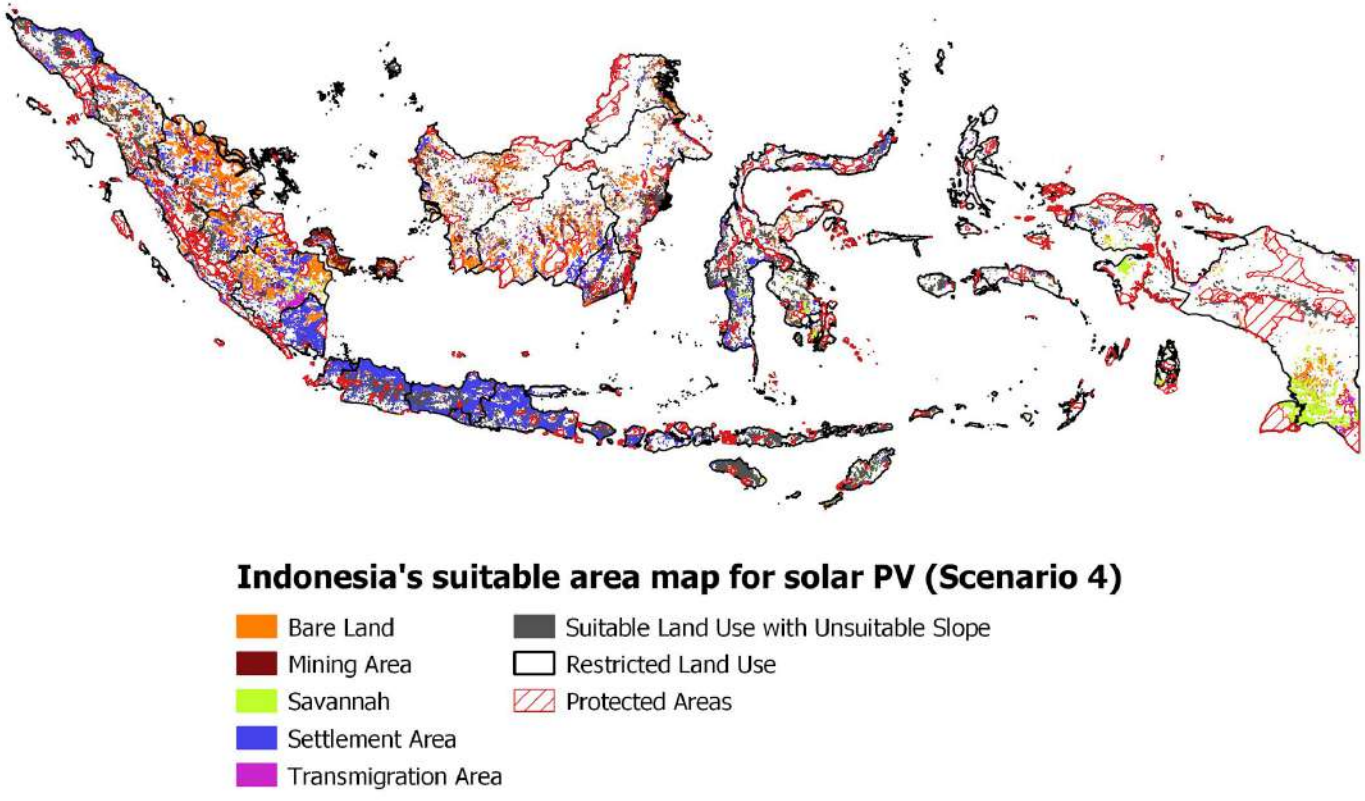

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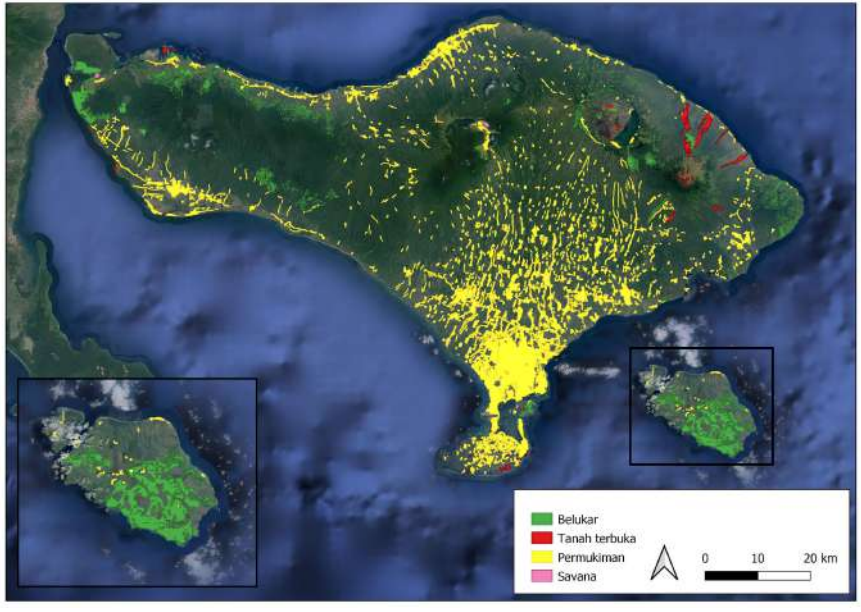

Potensi daerah total

Tipe lahan	Kapasitas potensial (GWp)	Produksi teknis (TWh/yr)
Pemukiman	19.8	30.4
Belukar	5.6	8.5
Savana	0.1	0.1
Tanah terbuka	0.9	1.4
Total	**26.4**	**40.5**

Potensi Nusa Penida

Tipe lahan	Kapasitas potensial (GWp)	Produksi teknis (TWh/yr)
Pemukiman	0.8	1.2
Belukar	2.4	3.8
Total	**3.2**	**5.0**