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Review article

Solar energy status in the world: A comprehensive review

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ABSTRACT

The utilization of renewable energy as a future energy resource is drawing significant attention worldwide. The contribution of solar energy (including concentrating solar power (CSP) and solar photovoltaic (PV) power) to global electricity production, as one form of renewable energy sources, is generally still low, at 3.6%. However, it has firmly established itself among other renewable energy technologies, comprising nearly 31% of the total installed renewable energy capacity in 2022, making it the second most installed renewable energy resource behind hydropower energy. The present review study, through a detailed and systematic literature survey, summarizes the world solar energy status along with the published solar energy potential assessment articles for 235 countries and territories as the first step toward developing solar energy in these regions. A comparison of the solar power status among countries and territories has been provided, considering their concentrated solar power and PV installed capacities for each continent. Although there has been a significant increase of approximately 22% in global solar energy installed capacity between 2021 and 2022, the literature survey reveals that clear gaps still exist in the field of solar energy. In the next three decades, the solar PV field can advance to become the second prominent generation source by constructing more solar farms, allowing countries to generate approximately 25% of the world's total electricity needs by 2050.

1. Introduction

The rapid depletion of fossil fuels, which accounts for nearly 80% of global energy consumption, demands an urgent need for research aimed at finding sustainable and renewable energy alternatives (Tester et al., 2012). Solar, hydropower, geothermal, biomass, and wind energy sources have been proposed and widely studied (Mohammed et al., 2013; Al-Ali and Dincer, 2014; Singh and Nachtnebel, 2016; Bahrami et al., 2017; Bahrami and Okoye, 2018; Okoye et al., 2018; Bahrami et al., 2019a; Bahrami et al., 2019b; Teimourian et al., 2020). These studies include, but are not limited to, assessing technical design viability, economic feasibility, optimization, and conducting social assessments using various models. Solar energy is a widely distributed, sustainable, and renewable energy source. As a renewable resource, solar energy has the capability to replace the widely used fossil fuel resource in the near future. While the contribution of solar energy to global electricity production remains generally low at 3.6%, it has firmly established itself among other renewable energy technologies, comprising nearly 31% of the total installed renewable energy capacity in 2022 (IRENA, 2023). With an installed capacity of 1053 GW in 2022, solar energy is the second most installed renewable energy technology, following hydropower technology with 1392 GW. (IRENA, 2023).

The global installed solar capacity over the past ten years and the contributions of the top fourteen countries are depicted in Tables 1 and 2 (IRENA, 2023). Table 1 shows a tremendous increase of approximately 22% in solar energy installed capacity between 2021 and 2022. While China, the US, and Japan are the top three installers, China's relative contribution accounts for nearly 37% of the entire solar installation in 2022. Fig. 1 illustrates the contribution of energy sources to both electricity generation and total installed power capacity by 2050. In 2016, as depicted in Fig. 1, renewables contributed to about 30% of the global installed capacity, providing nearly a quarter of global electricity production. The solar power (PV+CSP) accounted for nearly 8% of the renewable electricity production. As shown in Fig. 1, by 2050, solar PV technology is projected to have the largest installed capacity (8519 GW), making it the second most prominent generation source behind wind power, and it is expected to generate approximately 25% of total electricity needs by 2050.

Through a systematic literature survey, this review study summarizes the world solar energy status (including concentrating solar power

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Table 1
Global installed solar capacity from 2013 to 2022.

	Solar energy capacity (MW)									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
World	140 514	180 712	228 920	301 082	395 947	489 306	592 245	720 429	861 537	1 053 115
Africa	716	1 709	2 242	3 455	5 200	8 150	9 493	10 819	11 628	12 641
Asia	36 225	60 691	90 581	140 489	211 853	276 406	332 854	410 326	485 413	597 573
Europe	84 189	91 095	99 604	106 173	112 299	121 603	142 272	162 795	190 143	227 799
N. America	13 645	20 129	27 043	38 731	47 828	57 664	69 656	86 493	107 192	126 443
S. America	198	465	921	1 589	3 672	5 512	8 562	13 164	20 795	32 773
Oceania	4 610	5 358	6 079	6 860	7 576	8 881	13 293	18 357	23 342	27 400

Table 2
Top fourteen solar energy installers in 2022.

N/s	Country	Installed capacity (GW)
1	China	393.0
2	USA	113.1
3	Japan	78.8
4	Germany	66.5
5	India	63.1
6	Australia	26.8
7	Italy	25.1
8	Brazil	24.1
9	Netherlands	22.6
10	Korea Rep	20.9
11	Spain	20.5
12	Viet Nam	18.5
13	France	17.4
14	UK	14.4

and solar PV power) along with the published solar energy potential assessment articles for 235 countries and territories as the first step toward developing solar energy in these regions. A comparison of the solar power status among countries and territories has been provided, considering their concentrated solar power and PV installed capacities for each continent. The literature survey reveals that clear gaps still exist in the field of solar energy. In the next three decades, the solar PV field can advance to become the second prominent generation source by constructing more solar farms, allowing countries to generate approximately 25% of the world's total electricity needs by 2050.

2. Data and methodology

Identifying problems and proposing solutions as academic research can be seen as the initial step toward developing the industry of a country. This review paper attempts to highlight the gap between academic energy research and its ultimate observable impact on the energy industry of nations. For each country, a comprehensive effort is made to define the current operational solar power status and its corresponding academic solar energy research. The presented information can help bridge the mentioned gaps and serve as a valuable guide for researchers, designers, and policymakers looking to promote solar energy adoption in the electricity generation mix of countries. To accomplish this objective, the study utilized Elsevier's Scopus, Google Scholar database, and bibliographic research techniques to collect materials identified as

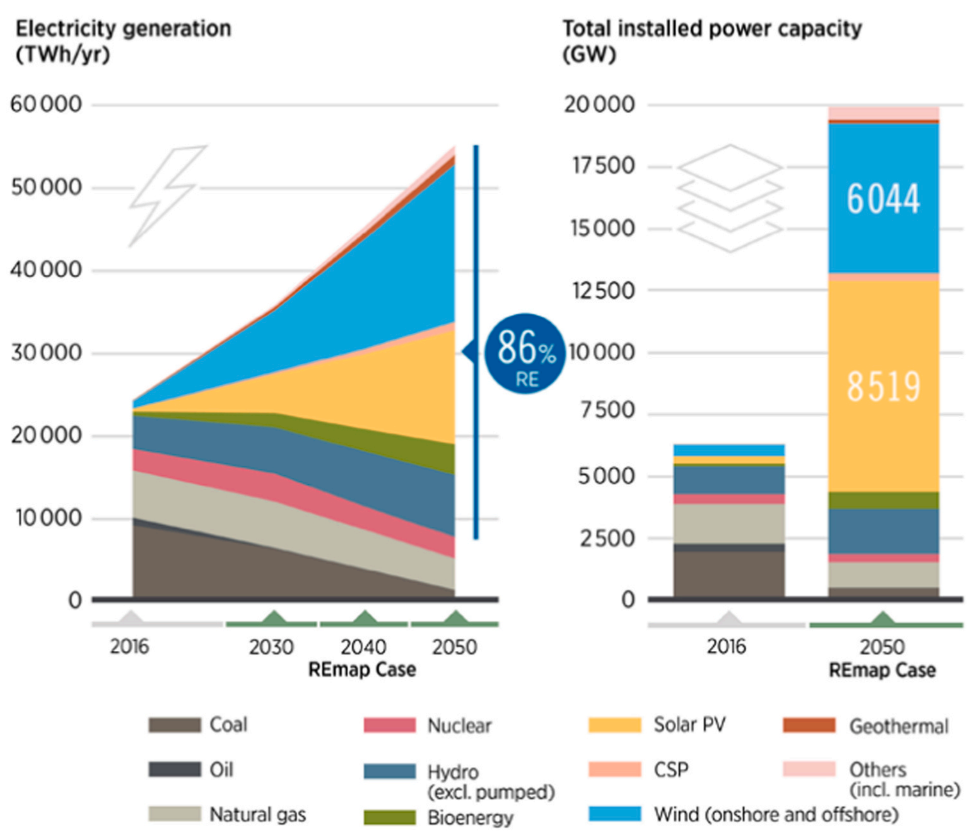

Fig. 1. The contribution of energy sources in both electricity generation and total installed power capacity by 2050 (IRENA, 2019a).

Table 3
Global installed solar PV capacity from 2013 to 2022.

	Solar PV capacity (MW)									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
World	136 572	176 113	224 070	296 112	390 878	483 495	585 868	713 918	855 162	1 046 614
Africa	651	1 544	1 917	3 030	4 675	7 165	8 408	9 734	10 543	11 556
Asia	36 055	60 346	90 236	140 125	211 488	275 827	332 111	409 433	484 496	596 530
Europe	81 878	88 783	97 292	103 861	109 987	119 291	139 951	160 474	187 822	225 478
N. America	12 358	18 463	25 285	36 973	46 070	55 890	67 881	84 728	105 695	124 946
S. America	198	465	921	1 589	3 672	5 512	8 562	13 164	20 687	32 665
Oceania	4 607	5 355	6 076	6 857	7 574	8 878	13 290	18 354	23 339	27 397

Table 4
Top fourteen solar PV energy installers in 2022.

N/s	Country	Installed capacity (GW)
1	China	392.4
2	USA	111.5
3	Japan	78.8
4	Germany	66.5
5	India	62.8
6	Australia	26.8
7	Italy	25.1
8	Brazil	24.1
9	Netherlands	22.6
10	South Korea	20.9
11	Viet Nam	18.5
12	Spain	18.2
13	France	17.4
14	UK	14.4

source type, keyword, subject area, source title, country, journal articles, or conference proceedings. This process aimed to address solar energy potential assessment articles for 235 countries and territories as the first step toward developing solar energy in these regions.

3. Solar PV energy

3.1. Solar PV installed capacity

The global installed solar PV capacity over the past ten years and the contributions of the top fourteen countries are presented in Tables 3 and 4 (IRENA, 2023). Europe was the leading contributor to global solar PV projects in the early years of solar PV development. In 2013, sixty percent of the world's solar PV installations were related to this continent, as indicated in Table 3. Rapid solar PV development has occurred in other areas since 2013, particularly in China. In 2017, China became the largest solar PV market, outperforming Europe, with approximately 1/3 of the world's installed capacity. The world's cumulative installed solar PV power capacity passed 1046 GW in 2022 (IRENA, 2023).

Table 3 shows a tremendous increase of approximately 22% (192 GW) in solar PV installed capacity between 2021 and 2022. While China, the US, and Japan are the top three installers, China's relative contribution accounts for nearly 37% of the entire solar PV installation in 2022. In 2022, the most significant expansion in the solar PV market occurred in China, the US, and India, with increments of 86.1 GW, 17.8 GW, and 13.5 GW, respectively (IRENA, 2023).

Fig. 2 shows the contribution of each continent in the world's solar PV installed capacity in 2018, followed by 2030 and 2050 based on IRENA's REmap analysis. In comparison to the PV installations in 2018 (481 GW), the world's PV installed capacity is projected to increase almost six times by 2030 (to 2841 GW) and almost 18 times by 2050 (to 8519 GW, of which the distributed scale (rooftop) would account for 40% while the remaining 60% would be utility scale). Asia will proceed to lead the solar PV market by about 65% of the world's PV installations (mainly China with 76% of the total), followed by North America at 15% (primarily the US with over 90% of the total) and Europe at 10% by 2030. By 2050, Asia, primarily China, is expected to maintain its leadership in the solar PV market with 4837 GW (about 57% of the world's PV installations), followed by North America at 21% and Europe at 11%. Meanwhile, a much larger market growth is anticipated for both Africa and South America by 2050, as shown in Fig. 2.

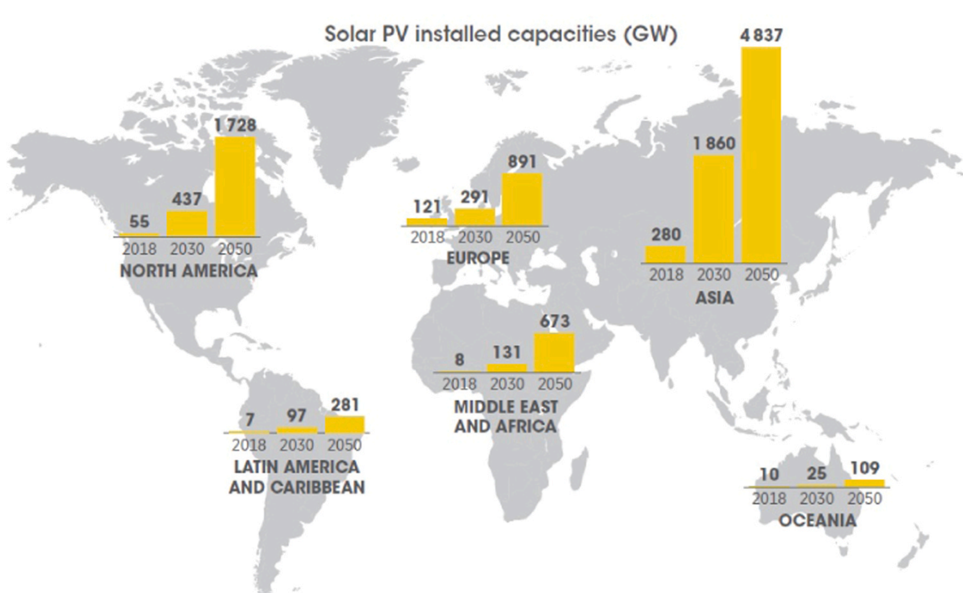

Fig. 2. The world solar PV installed capacity by 2050 (IRENA, 2019a).

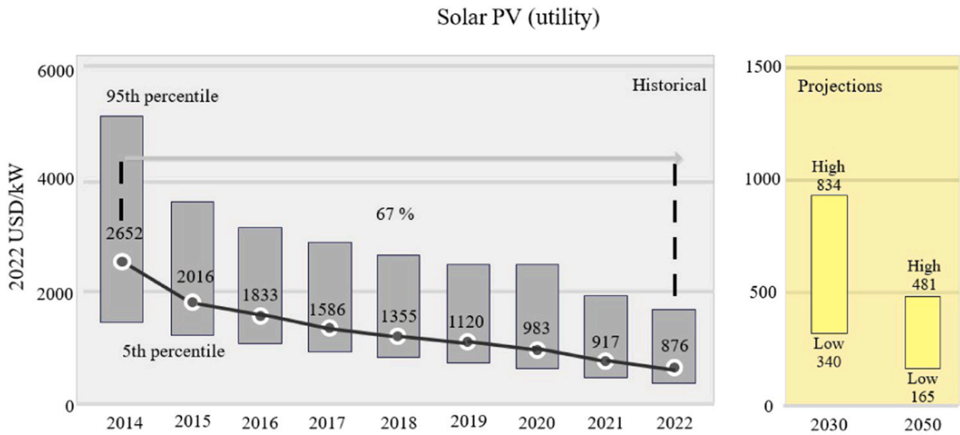

Fig. 3. The global weighted-average total installed cost of solar PV projects since 2014, followed by 2050 (IRENA, 2019a; IRENA, 2022).

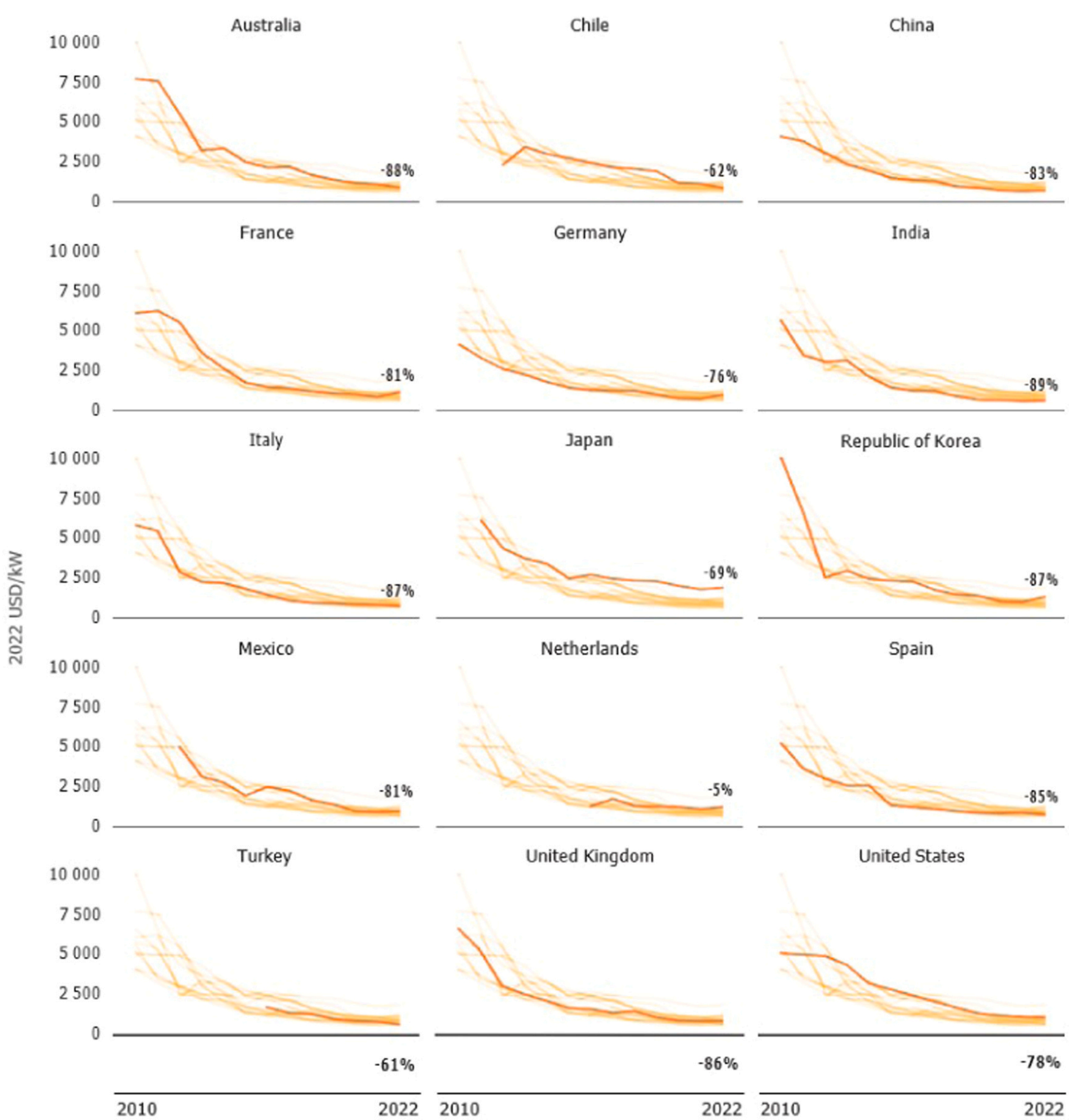

Fig. 4. The total installed cost trends for solar PV projects in major markets since 2010 (IRENA, 2022).

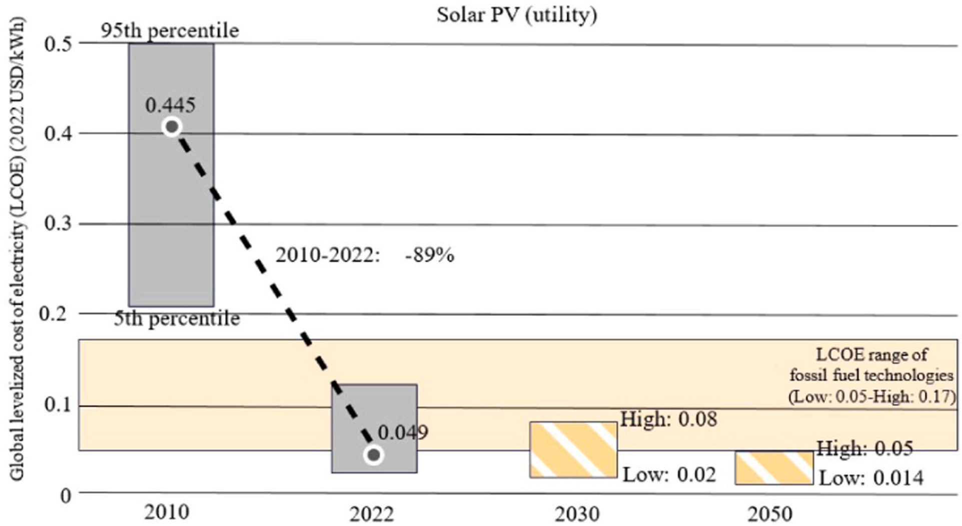

Fig. 5. The global levelized cost of electricity for solar PV projects since 2010, followed by 2050 (IRENA, 2019a; IRENA, 2022).

Fig. 6. Regional weighted average levelized cost of electricity for solar PV projects in the major markets since 2010 (IRENA, 2022).

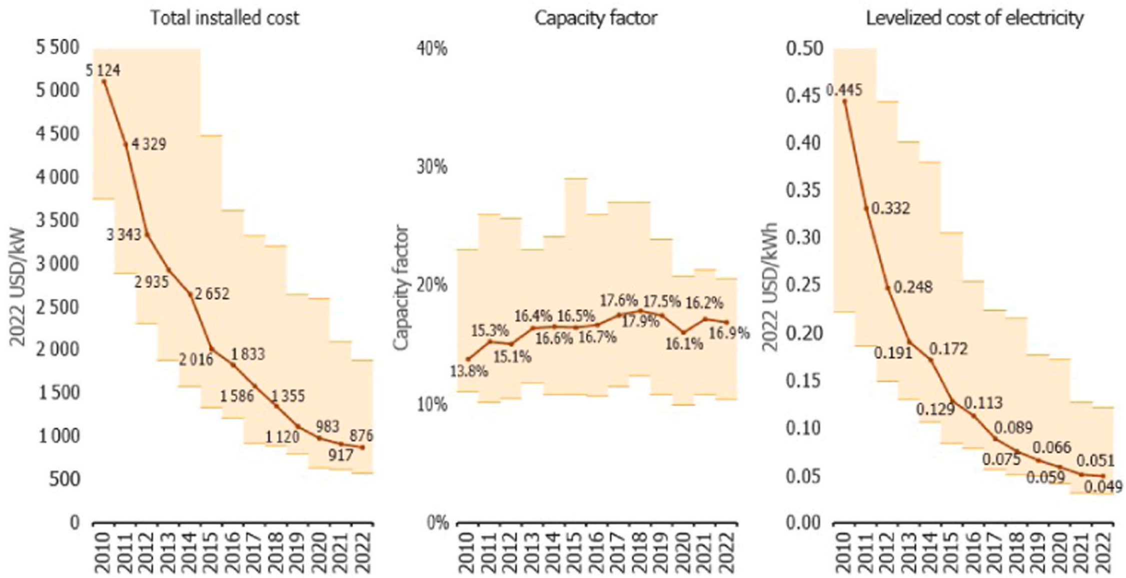

Fig. 7. The global weighted average LCOE, capacity factor, and total installed costs for solar PV projects since 2010 (IRENA, 2022).

3.2. Solar PV total installed costs

Fig. 3 shows the variation of the global weighted-average total installed cost of solar PV projects since 2014, followed by 2050. It is seen that the global weighted-average total installed cost of solar PV projects reduced by about 67% from 2652 USD/kW in 2014 to 876 USD/kW in 2022. The recent reduction in the 2022 weighted-average total installed cost compared to the 2021 value was about 4%. The results from IRENA's REmap analysis also indicate that the global weighted-average total installed cost of solar PV projects would reduce from 876 USD/kW in 2022 to an average within 340–834 USD/kW by 2030 and 165–481 USD/kW by 2050.

Fig. 4 shows the variation of the total installed cost trends of solar PV projects in fifteen major markets between 2010 and 2022. It is observed that the country-weighted average total installed cost decreased from 2010 to 2022 in the top fifteen markets, with India experiencing the maximum reduction (89%) and Germany the minimum reduction (76%) in the total installed cost. The reduction in the 2022 total installed cost, compared to the 2021 values, varied from 22% in Chile to a low of 4% in the US, while the increase in the 2022 total installed cost, compared to the 2021 values, ranged from 34% in Germany and France to a low of 2% in India. In 2022, among the top fifteen markets, India had the lowest total installed cost at 640 USD/kW, followed by Turkey (690 USD/kW), China (715 USD/kW), Italy (771 USD/kW), and Spain (778 USD/kW). Among the aforementioned fifteen major markets, Japan had the highest 2022 total installed cost at 1905 USD/kW, followed by the Netherlands (1221 USD/kW) and France (1157 USD/kW).

3.3. Solar PV levelized cost of electricity

Fig. 5 shows the variation of the global weighted-average LCOE for solar PV projects since 2010. It is seen that the global weighted-average LCOE of solar PV technology reduced by about 89 % from 0.445 USD/kWh in 2010 to 0.049 USD/kWh in 2022. It is noticeable that the LCOE of PV technology has dropped into the range of fossil fuel electricity costs since 2014. The recent 2022 global weighted-average LCOE reduction compared to the 2021 value was about 3%. The results from IRENA's REmap analysis also indicate that the LCOE for solar PV projects would reduce from 0.049 USD/kWh in 2022 to an average within 0.02–0.08 USD/kWh by 2030 and 0.014–0.05 USD/kWh by 2050.

Fig. 6 shows the regional weighted-average LCOE of solar PV projects in the top fifteen markets since 2010. It is seen that the country-weighted average LCOE reduced within 2010–2022 in the top fifteen markets, and the maximum and minimum reductions in the LCOE belong to Australia (91%) and the US (75%), respectively. The reduction in the 2022 LCOE, compared to the 2021 values, varied from 9% in Chile and Australia to a low of 1% in the US. Meanwhile, the increase in the 2022 LCOE, compared to the 2021 values, ranged from 27% in Germany and Mexico to a low of 2% in India. In 2022, the observed countries' weighted-average LCOE was within 0.037–0.1 USD/kWh. The lowest 2022 weighted-average LCOE belongs to both India and China (0.037 USD/kWh), followed by Australia (0.041 USD/kWh), Chile (0.042 USD/kWh), and Spain (0.046 USD/kWh). Meanwhile, Japan recorded the highest 2022 weighted-average LCOE at 0.092 USD/kWh at the highest end of the cost chart.

Table 5
Global installed concentrated solar capacity from 2013 to 2022.

	Concentrated solar capacity (MW)									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
World	3 942	4 599	4 850	4 970	5 069	5 811	6 377	6 511	6 375	6 501
Africa	65	165	325	425	525	985	1 085	1 085	1 085	1 085
Asia	170	345	345	365	365	580	744	894	918	1 044
Europe	2 311	2 312	2 312	2 312	2 312	2 312	2 321	2 321	2 321	2 321
N. America	1 286	1 667	1 758	1 758	1 758	1 774	1 775	1 765	1 497	1 497
S. America	0	0	0	0	0	0	0	0	108	108
Oceania	3	3	3	3	2	3	3	3	3	3

Table 6
Top ten concentrated solar energy installers in 2022.

N/s	Country	Installed capacity (GW)
1	Spain	2.3
2	USA	1.5
3	China	0.59
4	Morocco	0.54
5	South Africa	0.50
6	India	0.34
7	Israel	0.24
8	Chile	0.11
9	UAE	0.10
10	Saudi Arabia	0.05

3.4. Solar PV capacity factor

Fig. 7 shows the variation of the global weighted-average capacity factor for solar PV projects between 2010 and 2022. It is observed that there is a tendency towards higher capacity factors from 13.8% in 2010 to 16.9% in 2022. The observed growth in the capacity factor is mainly due to three key factors, 1) performance enhancement of the systems by reducing losses, 2) using solar tracking systems, and 3) tendency towards deployment in areas with higher radiation levels.

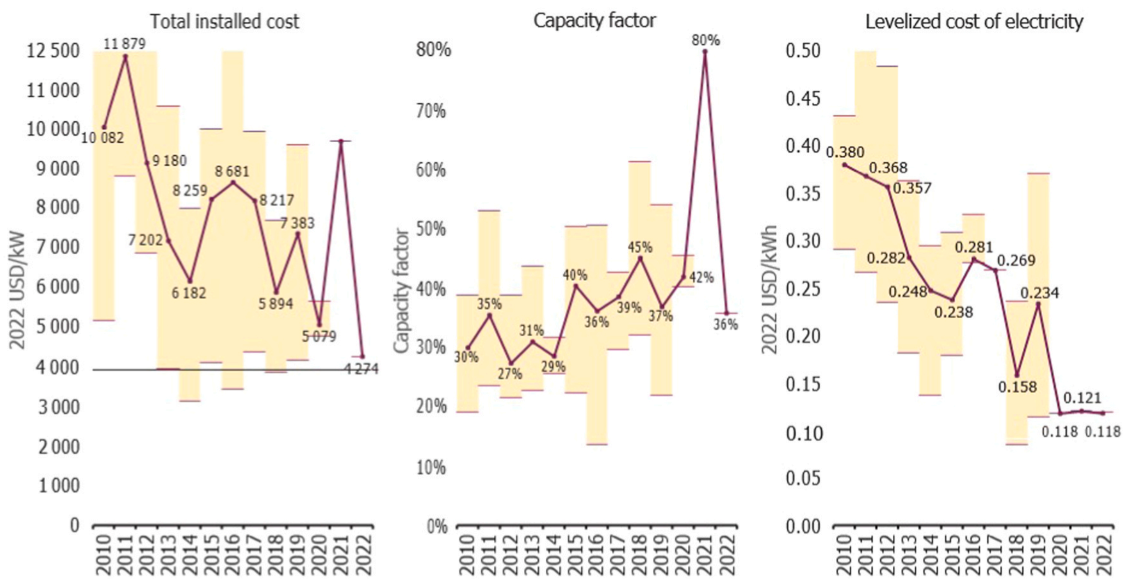

Fig. 8. The global weighted average LCOE, capacity factor, and total installed costs for CSP projects between 2010 and 2022 (IRENA, 2022).

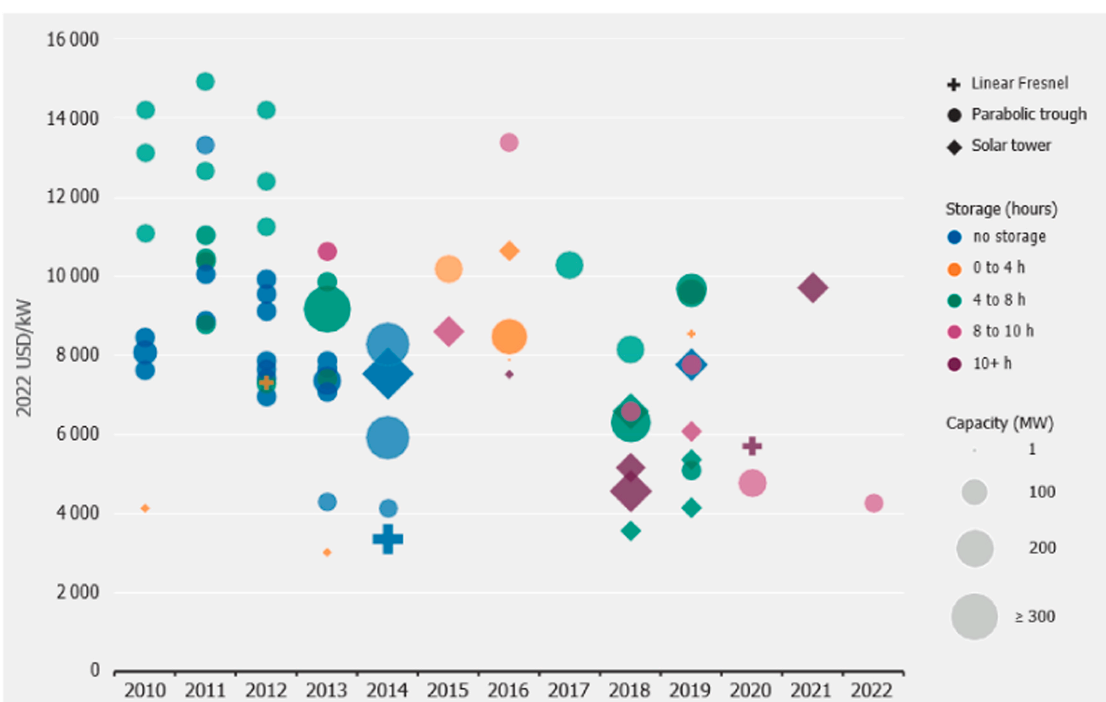

Fig. 9. The total installed costs for CSP projects between 2010 and 2022 (IRENA, 2022).

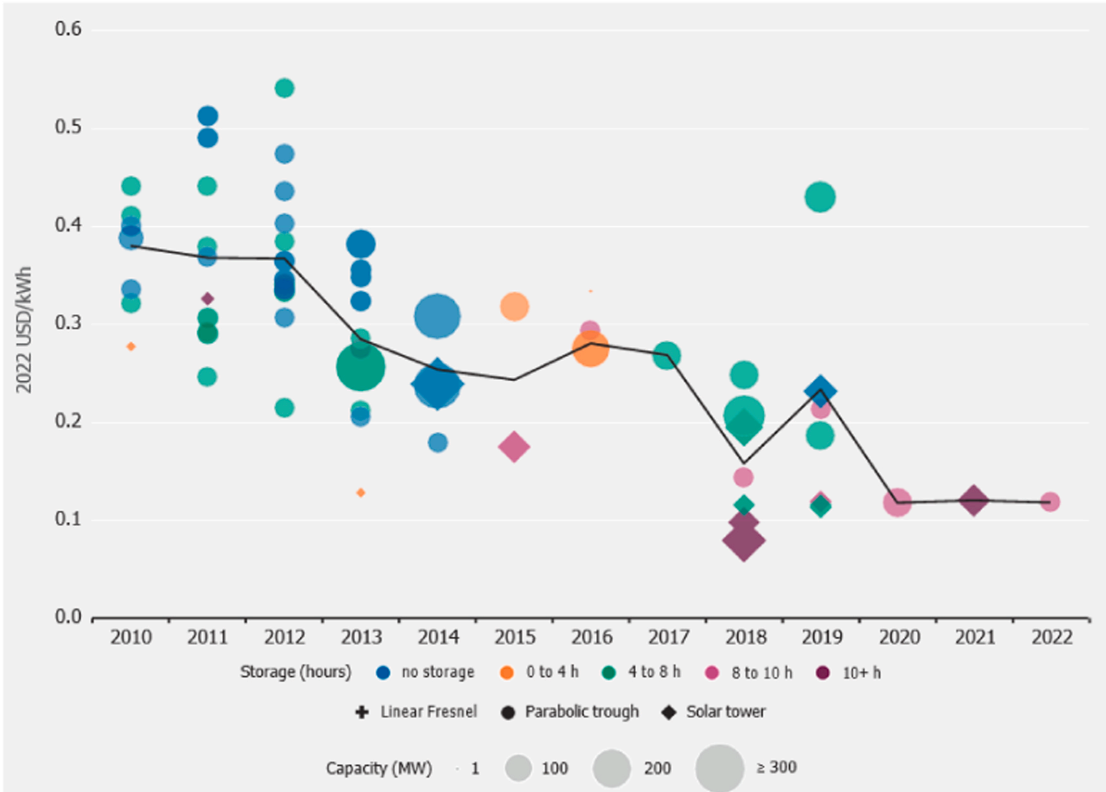

Fig. 10. The levelized cost of electricity for CSP projects between 2010 and 2022 (IRENA, 2022).

4. Concentrated solar power (CSP)

4.1. Concentrated solar installed capacity

The global installed concentrated solar capacity over the past ten years and the contributions of the top ten countries are depicted in Tables 5 and 6 (IRENA, 2023). Europe has been the leading contributor to global concentrated solar projects since the early years of CSP development. In 2013, 58% of the world CSP installations were related to Europe, followed by North America (32%), and Asia (4%), as shown in Table 5. Rapid CSP development has occurred in other areas since 2013, particularly in Africa and Asia. In 2022, the relative contributions of Asia and Africa were recorded both at around 16% of the entire CSP installations. The world's cumulative installed capacity passed 6.5 GW for CSP in 2022 (IRENA, 2023).

Based on Table 6, while Spain, the US, and China are the top three installers, the relative contribution of Spain is nearly 35% of the entire CSP installation, followed by the US (24%) and China (9%) in 2022.

4.2. Concentrated solar total installed costs

Fig. 8 shows the global weighted-average total installed costs for CSP projects between 2010 and 2022. As shown in Fig. 8, the world-weighted average total installed cost of CSP technology reduced by about 58 % from 10,082 USD/kW in 2010 to 4274 USD/kW in 2022. The recent 56% reduction in the 2022 total installed cost compared to the 2021 value will likely continue in the upcoming years due to China's participation as a major competitor by deploying more CSP plants with lower overall installed prices. Fig. 9 shows the variation of the total installed cost for CSP projects for various technology types and storage durations between 2010 and 2022. Based on the storage duration, the location of the projects, the plant capacity, and the used technology type (Linear Fresnel, Parabolic Trough, Solar Tower), a wide range of installed costs has been observed each year for the CSP technology. For instance, in 2018, the variation range was between 3400 and 7000 USD/kW with higher storage capacities (between 4 and 8 h or even more). It is also seen that there have been no CSP projects with a Linear Fresnel design since 2014, except for one exception in 2020, as shown in Fig. 9.

4.3. Concentrated solar levelized cost of electricity

Fig. 8 shows the global weighted-average LCOE for CSP projects between 2010 and 2022. As shown in Fig. 8, the global weighted-average LCOE of CSP technology reduced by about 69 % from 0.380 USD/kWh in 2010 to 0.118 USD/kWh in 2022. This makes the CSP the most expensive source among renewable resources at the moment. However, it's noteworthy that this cost now falls within the 2022 range of fossil fuel-fired costs, which is between 0.05 and 0.27 USD/kWh. Given the limited CSP deployment in recent times, with only one CSP plant commissioned in China in 2022, there has been a 2% reduction in the 2022 LCOE compared to the 2021 value. This reduction is primarily attributed to China's emergence as a major competitor in the CSP field. Fig. 10 shows the variation in the levelized cost of electricity for CSP projects across various technology types and storage durations between 2010 and 2022.

Currently, higher capacity factors and lower total installed costs can contribute to a reduction in the LCOE for CSP. Additionally, further decreases in the LCOE can be achieved by implementing storage technology in CSP projects. By recognizing the fact that storage minimizes the LCOE, there have been no CSP projects without storage capacity since 2014, as shown in Fig. 10. It is also seen that the average storage duration in 2018 (8.3 h) is more than double the 2010 value (3.6 h).

4.4. Concentrated solar capacity factor

Fig. 8 shows the global weighted-average capacity factor for CSP projects between 2010 and 2022. The global weighted-average capacity factor increased from 30% in 2010 to 42% in 2020, as illustrated in

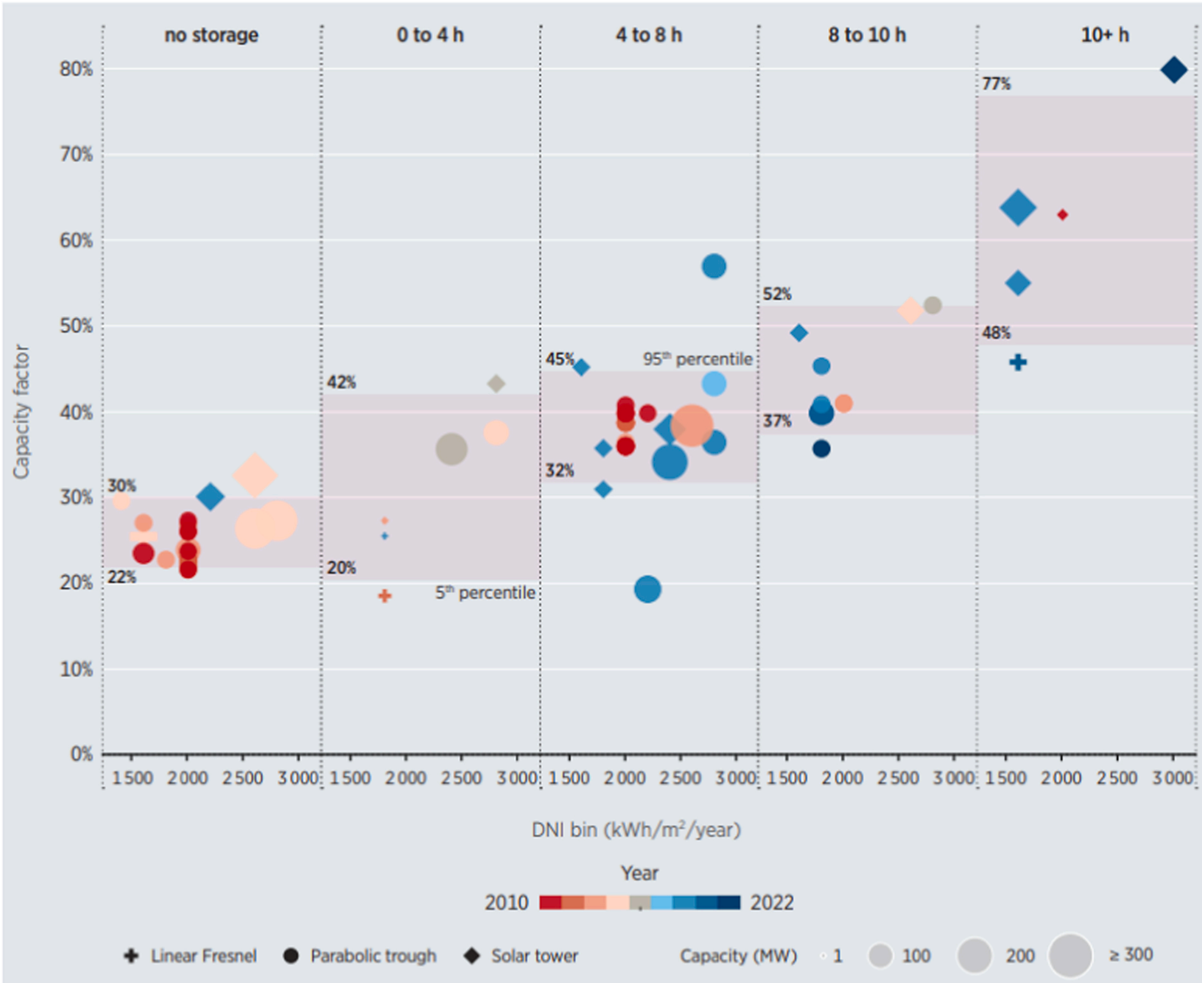

Fig. 11. The capacity factor for CSP projects between 2010 and 2022 (IRENA, 2022).

Fig. 8. Fig. 11 shows the variation in the capacity factor for CSP projects across various levels of direct normal irradiance, technology types, and storage durations between 2010 and 2022. It is observed in recent years that there is a tendency towards higher storage capacity along with a higher capacity factor. The increase in the capacity factor is primarily attributed to the shift from Spain to locations with higher direct radiation levels ranging from 2500 to 3000 kWh/m^2/year since 2014. (IRENA, 2022).

5. Solar energy potential assessment articles in the continents

The accurate design of a Solar Energy Conversion System (SECS) requires a good understanding of the solar characteristics at the location of interest. For this reason, selecting the right location is crucial, as it impacts not only the technical but also the economic viability of the proposed design. In addition to the location-specific solar irradiation data, other parameters, including ambient temperature, wind speed, and the amount of dust covering solar PV systems, are crucial factors in converting solar power to electricity. To harness solar energy in any location of interest, the first essential step is to assess the feasibility of the system (Mostafaeipour et al., 2014). For this reason, numerous studies have assessed the utilization and feasibility of solar energy in various locations across continents as the initial step toward solar energy development in these countries.

5.1. Europe

Table 7 presents the solar capacity in Europe at the end of 2022 (IRENA, 2023), alongside studies assessing the solar energy potential of countries and territories in the continent. These assessments mark the initial steps toward solar energy development in the region. In the European continent, Albania (Maraj et al., 2014), Austria (Hartner et al., 2015; Komendantova et al., 2018), Belgium (Journée and Bertrand, 2010; Demain et al., 2013), Bosnia and Herzegovina (Pavlovic et al., 2013), Bulgaria (Ganev et al., 2014), Croatia (Hrastnik and Frankovi, 2001; Zhang et al., 2015), Czech Republic (Hofierka et al., 2014), Denmark (Dragsted and Furbo, 2012), Estonia (Russak, 1991), Finland (Aslani et al., 2013), France (Notton et al., 2017), Germany (Mainzer et al., 2014; Romero Rodríguez et al., 2017), Greece (Karteris et al., 2013), Hungary (Horváth et al., 2016), Ireland (Berger, 1998; Murphy and McDonnell, 2017), Italy (Bocca et al., 2015), Kosovo (Veseli and Sofiu, 2019), Latvia (Shipkovs et al., 2015), Lithuania (Vasarevicius and Martavicius, 2011), Malta (Yousif et al., 2013), Netherlands (Bakker et al., 2019), Norway (Adaramola, 2016; Babar et al., 2019), Poland (Kulesza, 2017), Portugal (Santos et al., 2014), Romania (BĂadescu, 1990; Sfîcă et al., 2017), Russia (Daus et al., 2016; Izmailov et al., 2019), Serbia (Luković et al., 2015; Kostić and Mikulović, 2017), Slovakia (Hofierka and Kaňuk, 2009; Hofierka et al., 2014), Slovenia (Zakšek et al., 2005; Brumen et al., 2014), Spain (Carrión et al., 2008; Izquierdo et al., 2011; Yousif et al., 2013), Sweden (Wallén, 1966; Kozarcanin and Andresen, 2018), Switzerland (Mohajeri et al., 2016; Assouline et al., 2017), UK (Tham et al., 2009; Palmer et al., 2019), Ukraine (Rybchenko

Table 7
Europe installed capacity.

Country	CSP capacity (MW)	PV Capacity (MW)	Reference
Albania	-	29	(Maraj et al., 2014)
Andorra	-	4	-
Austria	-	3 548	(Hartner et al., 2015; Komendantova et al., 2018)
Belarus	-	269	-
Belgium	-	6 898	(Journée and Bertrand, 2010; Demain et al., 2013)
Bosnia & Herzegovina	-	107	(Pavlovic et al., 2013)
Bulgaria	-	1 948	(Ganev et al., 2014)
Croatia	-	182	(Hrastnik and Frankovi, 2001; Zhang et al., 2015)
Czech Republic	-	2 627	(Hofierka et al., 2014)
Denmark	-	2 490	(Dragsted and Furbo, 2012)
Estonia	-	535	(Russak, 1991)
Faroe Islands	-	-	-
Finland	-	591	(Aslani et al., 2013)
France	9	17 410	(Notton et al., 2017)
Germany	2	66 552	(Mainzer et al., 2014; Romero Rodríguez et al., 2017)
Gibraltar	-	-	-
Greece	-	5 557	(Karteris et al., 2013)
Hungary	-	2 988	(Horváth et al., 2016)
Iceland	-	7	-
Ireland	-	135	(Berger, 1998; Murphy and McDonnell, 2017)
Italy	6	25 077	(Bocca et al., 2015)
Kosovo	-	10	(Veseli and Sofiu, 2019)
Latvia	-	56	(Shipkovs et al., 2015)
Liechtenstein	-	-	-
Lithuania	-	568	(Vasarevicius and Martavicius, 2011)
Luxembourg	-	319	-
Macedonia	-	94	-
Malta	-	206	(Yousif et al., 2013)
Moldova	-	19	-
Monaco	-	-	-
Montenegro	-	26	-
Netherlands	-	22 590	(Bakker et al., 2019)
Norway	-	321	(Adaramola, 2016; Babar et al., 2019)
Poland	-	11 167	(Kulesza, 2017)
Portugal	-	2 536	(Santos et al., 2014)
Romania	-	1 414	(BĂadescu, 1990; Sfîcă et al., 2017)
Russia	-	1 816	(Daus et al., 2016; Izmailov et al., 2019)
San Marino	-	-	-
Serbia	-	137	(Luković et al., 2015; Kostić and Mikulović, 2017)
Slovakia	-	537	(Hofierka and Kaňuk, 2009; Hofierka et al., 2014)
Slovenia	-	632	(Zakšek et al., 2005; Brumen et al., 2014)
Spain	2 304	18 214	(Carrión et al., 2008; Izquierdo et al., 2011; Yousif et al., 2013)
Sweden	-	2 606	(Wallén, 1966; Kozarcanin and Andresen, 2018)
Switzerland	-	4 134	(Mohajeri et al., 2016; Assouline et al., 2017)
UK	-	14 412	(Tham et al., 2009; Palmer et al., 2019)
Ukraine	-	8 062	(Rybchenko and Savchuk, 2017; Mandryk et al., 2020)

and Savchuk, 2017; Mandryk et al., 2020).

According to Table 7, in 2022, Germany, Italy, and the Netherlands ranked as the top three European solar energy installers (solar PV and CSP), with total installed capacities of 66.5 GW, 25.1 GW, and 22.6 GW, respectively. The same ranking pattern holds for the solar PV category, with Germany leading the continent at 66.5 GW (99.99% of its total solar capacity), followed by Italy (25.1 GW, 99.97% of its total solar capacity) and the Netherlands (22.6 GW, 100.0% of its total solar capacity). The ranking pattern is quite different in the CSP category. In the case of CSP installers, Spain, France, and Italy were the top three European CSP installers in 2022, with installed capacities of 2.3 GW, 0.01 GW, and 0.006 GW, respectively.

5.2. Africa

Table 8 presents the solar capacity in Africa at the end of 2022 (IRENA, 2023), along with studies assessing the solar energy potential of countries and territories in the continent. These assessments mark the initial steps toward solar energy development in the region. In the African continent, Algeria (Gairaa and Bakelli, 2013; Guermoui and Rabehi, 2018), Angola (Puati Zau and Daniel Chowdhury B, 2018), Benin (Amoussa, 1992), Botswana (Mutoko and Mutoko, 2019), Burkina Faso (Ouedraogo and Yamegueu, 2019), Burundi (Lawin et al., 2019), Cape Verde (Qing and Niu, 2018), Cameroon (David et al., 2018), Chad (Soulouknga et al., 2017; Goni et al., 2019), Côte d'Ivoire (Sidibé et al., 2017; Kouassi et al., 2020), Djibouti (Pillot et al., 2013; Pillot et al., 2015), Egypt (Effat, 2013; Effat, 2016), Ethiopia (Drake and Mulugetta, 1996; Woldegiyorgis, 2019), Gambia (Kanteh Sakiliba et al., 2015), Ghana (Forson et al., 2004; Asumadu-Sarkodie and Asantewaa Owusu, 2016), Kenya (Oloo et al., 2015; Kariuki and Sato, 2018), Lesotho (Gopinathan, 1989; Gopinathan, 1991), Libya (Kutucu and Almryad, 2016; Belgasim et al., 2018), Madagascar (Randrianarinosy et al., 2018), Malawi (Madhlopa, 2006), Mali (Diarra and Akuffo, 2002), Mauritania (El-Mukhtar, 1983), Mauritius (Ramgolam and Soyjaudah, 2015; Singh Doorga et al., 2019), Morocco (Ouammi et al., 2012; Bouhal et al., 2018; Tazi et al., 2018), Mozambique (Cuamba et al., 2006), Namibia (Le Fol and Ndhlukula, 2017), Niger (Dankassoua et al., 2017), Nigeria (Fadare, 2009; Okoye et al., 2016), Reunion (Badosa et al., 2013; Jeanty et al., 2013), Rwanda (Safari and Gasore, 2009; Rodríguez-Manotas et al., 2018), Senegal (Wane et al., 2018), Seychelles (Brown et al., 2016), Sierra Leone (Massaquoi, 1988), Somalia (Habbane and McVeigh, 1986), South Africa (Munzhedzi and Sebitosi, 2009; Park et al., 2011; Zawilska and Brooks, 2011), South Sudan (Gudo et al., 2020), Sudan (Elagib and Mansell, 2000; Gamil et al., 2012), Tanzania (Alfayo and Uiso, 2002; Aly et al., 2017), Togo (Dzo Mawuefa Afenyiveh et al., 2019), Tunisia (El Ouderni et al., 2013; Chelbi et al., 2015), Uganda

Table 8
Africa installed capacity.

Country	CSP capacity (MW)	PV Capacity (MW)	Reference
Algeria	25	435	(Gairaa and Bakelli, 2013; Guermoui and Rabehi, 2018)
Angola	-	297	(Puati Zau and Daniel Chowdhury B, 2018)
Benin	-	28	(Amoussa, 1992)
Botswana	-	6	(Mutoko and Mutoko, 2019)
Burkina Faso	-	92	(Ouedraogo and Yamegueu, 2019)
Burundi	-	13	(Lawin et al., 2019)
Cape Verde	-	8	(Qing and Niu, 2018)
Cameroon	-	14	(David et al., 2018)
Central African Republic	-	-	-
Chad	-	1	(Souloukngа et al., 2017; Goni et al., 2019)
Comoros	-	4	-
Congo DR	-	20	-
Congo	-	1	-
Côte d'Ivoire	-	13	(Sidibé et al., 2017; Kouassi et al., 2020)
Djibouti	-	-	(Pillot et al., 2013, 2015)
Egypt	20	1 704	(Effat, 2013, 2016)
Equatorial Guinea	-	-	-
Eritrea	-	11	-
Eswatini	-	11	-
Ethiopia	-	21	(Drake and Mulugetta, 1996; Woldegiyorgis, 2019)
Gabon	-	1	-
Gambia	-	3	(Kanteh Sakiliba et al., 2015)
Ghana	-	98	(Forson et al., 2004; Asumadu-Sarkodie and Asantewaa Owusu, 2016)
Guinea	-	2	-
Guinea-Bissau	-	1	-
Kenya	-	307	(Oloo et al., 2015; Kariuki and Sato, 2018)
Lesotho	-	-	(Gopinathan, 1989, 1991)
Liberia	-	3	-
Libya	-	6	(Kutucu and Almryad, 2016; Belgasim et al., 2018)
Madagascar	-	33	(Randrianarinosy et al., 2018)
Malawi	-	143	(Madhlopa, 2006)
Mali	-	229	(Diarra and Akuffo, 2002)
Mauritania	-	89	(El-Mukhtar, 1983)
Mauritius	-	110	(Ramgolam and Soyjaudah, 2015; Singh Doorga et al., 2019)
Mayotte	-	30	-
Morocco	540	318	(Ouammi et al., 2012; Bouhal et al., 2018; Tazi et al., 2018)
Mozambique	-	108	(Cuamba et al., 2006)
Namibia	-	176	(Le Fol and Ndhlukula, 2017)
Niger	-	62	(Dankassoua et al., 2017)
Nigeria	-	37	(Fadare, 2009; Okoye et al., 2016)
Reunion	-	224	(Badosa et al., 2013; Jeanty et al., 2013)
Rwanda	-	25	(Safari and Gasore, 2009; Rodríguez-Manotas et al., 2018)
Saint Helena	-	-	-
São Tomé and Príncipe	-	-	-
Senegal	-	263	(Wane et al., 2018)
Seychelles	-	18	(Brown et al., 2016)
Sierra Leone	-	9	(Massaquoi, 1988)
Somalia	-	47	(Habbane and McVeigh, 1986)
South Africa	500	5 826	(Munzhedzi and Sebitosi, 2009; Park et al., 2011; Zawilska and Brooks, 2011)
South Sudan	-	14	(Gudo et al., 2020)
Sudan	-	190	(Elagib and Mansell, 2000; Gamil et al., 2012)
Tanzania	-	15	(Alfayo and Uiso, 2002; Aly et al., 2017)
Togo	-	57	(Dzo Mawuefa Afenyiveh et al., 2019)
Tunisia	-	197	(El Ouderni et al., 2013; Chelbi et al., 2015)
Uganda	-	94	(Mubiru and Banda, 2012; Biira and Kilama, 2014)
Western Sahara	-	-	-
Zambia	-	96	(Mwanza et al., 2017)
Zimbabwe	-	41	(Ziuku et al., 2014; Samu and Fahrioglu, 2017).

(Mubiru and Banda, 2012; Biira and Kilama, 2014), Zambia (Mwanza et al., 2017), Zimbabwe (Ziuku et al., 2014; Samu and Fahrioglu, 2017).

It is seen from Table 8 that South Africa, Egypt, and Morocco were the top three African solar power installers (solar PV and CSP) in 2022, with total installed capacities of 6.3 GW, 1.7 GW, and 0.8 GW, respectively. The ranking pattern differs in the solar PV category, with South Africa (5.8 GW) and Egypt (1.7 GW) leading as the top two solar power installers. The third position is held by Algeria (0.4 GW), followed by Morocco (0.3 GW). In the case of CSP installers, Morocco, South Africa, and Algeria were the top three African CSP installers in 2022, with installed capacities of 0.54 GW, 0.50 GW, and 0.03 GW, respectively.

5.3. Asia

Table 9 presents the solar capacity in Asia at the end of 2022 (IRENA, 2023), along with studies assessing the solar energy potential of countries and territories in the continent. These assessments mark the initial steps toward solar energy development in the region. In the Asian continent, Afghanistan (Mohammed Quraishee, 1969, Anwarzai and Nagasaka, 2017), Armenia (Gevorgyan and Sargsyan, 2007), Azerbaijan (Abbasov, 2015; Gulaliyev et al., 2020), Bahrain (Al-Sadah et al., 1990; Alnaser and Al-Attar, 1999), Bangladesh (Alam Hossain Mondal and Sadrul Islam, 2011; Nandi et al., 2013), Bhutan (Tenzin and Saini, 2019), Brunei (Mathew et al., 2013), Cambodia (De Schepper et al., 2015), China (Li et al., 2014; He and Kammen, 2016; Zhang et al., 2020),

Table 9
Asia installed capacity.

Country	CSP (MW)	PV Capacity (MW)	Reference
Afghanistan	-	33	(MohammedQuraishee, 1969,Anwarzai and Nagasaka, 2017)
Armenia	-	306	(Gevorgyan and Sargsyan, 2007)
Azerbaijan	-	51	(Abbasov, 2015; Gulaliyev et al., 2020)
Bahrain	-	12	(Al-Sadah et al., 1990; Alnaser and Al-Attar, 1999)
Bangladesh	-	537	(Alam Hossain Mondal and Sadrul Islam, 2011; Nandi et al., 2013)
Bhutan	-	-	(Tenzin and Saini, 2019)
Brunei	-	5	(Mathew et al., 2013)
Cambodia	-	456	(De Schepper et al., 2015)
China	596	392 436	(Li et al., 2014; He and Kammen, 2016; Zhang et al., 2020)
Cyprus	-	464	(Makrides et al., 2010; Ouria and Sevinc, 2018)
Georgia	-	18	-
India	343	62 804	(Ramachandra et al., 2011; Kapoor et al., 2014)
Indonesia	-	291	(Morrison and Sudjito, 1992; Rumbayan et al., 2012)
Iran	-	539	(Alamdari et al., 2013; Besarati et al., 2013)
Iraq	-	42	(Ahmad et al., 1983; Hussain and Mahdi, 2018)
Israel	242	4 169	(Becker, 2001; Fischhendler et al., 2015)
Japan	-	78 833	(Yang et al., 2001; Ohtake et al., 2013)
Jordan	-	1 914	(S. Alrwashdeh et al., 2018)
Kazakhstan	-	2 031	(Assamidanov et al., 2018; Pivina et al., 2018)
Kuwait	50	43	(Bou-Rabee and Sulaiman, 2015)
Kyrgyzstan	-	-	(Kiseleva et al., 2015)
Laos	-	34	-
Lebanon	-	440	(Sfeir, 1981)
Malaysia	-	1 933	(Sukarno et al., 2015; Abd. Aziz et al., 2016)
Maldives	-	36	(Ali et al., 2018)
Mongolia	100	95	(Adiyabat et al., 2006)
Myanmar	-	103	-
Nepal	-	117	(Pondyal et al., 1970; KC and Gurung, 2017)
North Korea	-	52	(Baek and Kim, 2019)
Oman	-	638	(Gastli and Charabi, 2010; Al-Saqlawi et al., 2018)
Pakistan	-	1 243	(Stökler et al., 2016; Tahir and Asim, 2018)
Palestine	-	192	(Fathi Nassar and Yassin Alsadi, 2019)
Philippines	-	1 625	(Teves et al., 2016; Farias-Rocha et al., 2019)
Qatar	-	805	(Alnaser and Almohanadi, 1990; Martín-Pomares et al., 2017)
Saudi Arabia	50	390	(Zell et al., 2015; Almarshoud, 2016)
Singapore	-	572	(Kannan et al., 2006; Ramkumar et al., 2019)
South Korea	-	20 975	(Nematollahi and Kim, 2017; Alsharif et al., 2018)
Sri Lanka	-	714	(Gunaratne, 1994)
Syria	-	60	(Elistratov and Ramadan, 2018; Ramadan and Elistratov, 2018)
Taiwan	-	9 724	(Ko et al., 2015; Kuo et al., 2018)
Tajikistan	-	-	(Kirpichnikova and Makhsumov, 2019)
Thailand	5	3 060	(Suphahitanukool et al., 2018; Ali et al., 2019)
Timor Leste	-	-	-
Turkey	1	9 425	(Sözen and Arcaklioğlu, 2005; Sözen et al., 2005)
Turkmenistan	-	-	(Pendzhiev, 2010)
UAE	100	2 940	(Islam et al., 2009; Gherboudj and Ghedira, 2016)
Uzbekistan	-	253	(Rakhimov et al., 2017)
Vietnam	-	18 474	(Nguyen and Pryor, 1996; Polo et al., 2015)
Yemen	-	257	(Khogali et al., 1983)

Cyprus (Makrides et al., 2010; Ouria and Sevinc, 2018), India (Ramachandra et al., 2011; Kapoor et al., 2014), Indonesia (Morrison and Sudjito, 1992; Rumbayan et al., 2012), Iran (Alamdari et al., 2013; Besarati et al., 2013), Iraq (Ahmad et al., 1983; Hussain and Mahdi, 2018), Israel (Becker, 2001; Fischhendler et al., 2015), Japan (Yang et al., 2001; Ohtake et al., 2013), Jordan (S. Alrwashdeh et al., 2018), Kazakhstan (Assamidanov et al., 2018; Pivina et al., 2018), Kuwait (Bou-Rabee and Sulaiman, 2015), Kyrgyzstan (Kiseleva et al., 2015), Lebanon (Sfeir, 1981), Malaysia (Sukarno et al., 2015; Abd. Aziz et al., 2016), Maldives (Ali et al., 2018), Mongolia (Adiyabat et al., 2006), Nepal (Pondyal et al., 1970; KC and Gurung, 2017), North Korea (Baek and Kim, 2019), Oman (Gastli and Charabi, 2010; Al-Saqlawi et al., 2018), Pakistan (Stökler et al., 2016; Tahir and Asim, 2018), Palestine (Fathi Nassar and Yassin Alsadi, 2019), Philippines (Teves et al., 2016; Farias-Rocha et al., 2019), Qatar (Alnaser and Almohanadi, 1990; Martín-Pomares et al., 2017), Saudi Arabia (Zell et al., 2015; Almarshoud, 2016), Singapore (Kannan et al., 2006; Ramkumar et al., 2019), South Korea (Nematollahi and Kim, 2017; Alsharif et al., 2018), Sri Lanka (Gunaratne, 1994), Syria (Elistratov and Ramadan, 2018; Ramadan and Elistratov, 2018), Taiwan (Ko et al., 2015; Kuo et al., 2018), Tajikistan (Kirpichnikova and Makhsumov, 2019), Thailand (Suphahitanukool et al., 2018; Ali et al., 2019), Turkey (Sözen and Arcaklioğlu, 2005; Sözen et al., 2005), Turkmenistan (Pendzhiev, 2010), UAE (Islam et al., 2009; Gherboudj and Ghedira, 2016), Uzbekistan (Rakhimov et al., 2017), Vietnam (Nguyen and Pryor, 1996; Polo et al., 2015), Yemen (Khogali et al., 1983).

It is observed from Table 9 that China, Japan, and India were the top three Asian solar energy installers (solar PV and CSP) in 2022, with total installed capacities of 393.0 GW, 78.8 GW, and 63.1 GW, respectively. The mentioned ranking pattern is the same for the solar PV category as China is the leader in the continent with 392.4 GW (99.8% of its total solar capacity), followed by Japan (78.8 GW, 100% of its total solar capacity) and India (62.8 GW, 99.4% of its total solar capacity). The same ranking pattern holds for the solar PV category, with China leading the continent at 392.4 GW (99.8% of its total solar capacity), followed by Japan (78.8 GW, 100% of its total solar capacity) and India (62.8 GW, 99.4% of its total solar capacity). The ranking pattern is quite different in the CSP category. In the case of CSP installers, China, India, and Israel are the top three Asian CSP installers in 2022, with installed capacities of 0.59 GW, 0.34 GW, and 0.24 GW, respectively.

Table 10
North and Central America installed capacity.

Country	CSP Capacity (MW)	PV Capacity (MW)	Reference
Anguilla	-	2	-
Antigua and Barbuda	-	13	-
Aruba	-	14	-
Bahamas	-	3	(Bingham et al., 2016)
Barbados	-	69	(Wyllie et al., 2018)
Belize	-	7	-
Bermuda	-	-	-
Bonaire, Sint Eustatius & Saba	-	7	-
British Virgin Islands	-	1	-
Canada	-	4 401	(McIntyre, 2012; Rosenbloom and Meadowcroft, 2014; Mansouri Kouhestani et al., 2019)
Cayman Islands	-	14	-
Costa Rica	-	74	(Nandwani, 2006)
Cuba	-	258	(Prieto and Oliveira, 2018; Morales Pedraza, 2019)
Curaçao	-	16	-
Dominica	-	-	-
Dominican Republic	-	742	(Guidi, 1993)
El Salvador	-	664	(Ambiente, 2005)
Greenland	-	1	-
Grenada	-	4	-
Guadeloupe	-	90	(Boland, 2015; Lauret et al., 2015)
Guatemala	-	105	(Orozco, 1987)
Haiti	-	3	(Oates et al., 2003)
Honduras	-	529	(El Blog del BID, 2018)
Jamaica	-	93	(Chen et al., 1994)
Martinique	-	78	-
Montserrat	-	1	-
Mexico	17	9 009	(Hernández-Escobedo et al., 2015; Villicaña-Ortiz et al., 2015)
Nicaragua	-	16	(Ranaboldo et al., 2015)
Panama	-	522	(Becker, 1987)
Puerto Rico	-	639	(Figueroa-Acevedo and Irizarry-Rivera, 2014; Harmsen et al., 2014)
Saint Barthelemy	-	-	-
Saint Kitts and Nevis	-	2	-
Saint Lucia	-	4	-
Sint Maarten	-	-	-
Saint Martin	-	1	-
Saint Pierre & Miquelon	-	-	-
Saint Vincent & the Grenadines	-	4	-
Trinidad and Tobago	-	4	(Boretti and Al-Zubaidy, 2019)
Turks & Caicos Islands	-	1	-
USA	1 480	111 535	(Jeppesen, 2004; Kodysh et al., 2013; Majumdar and Pasqualetti, 2019)
US Virgin Islands	-	10	-

5.4. North and Central America

Table 10 presents the solar capacity in North and Central America at the end of 2022 (IRENA, 2023), along with studies assessing the solar energy potential of countries and territories in the continent. These assessments mark the initial steps toward solar energy development in the region. In the North and Central American continent, Bahamas (Bingham et al., 2016), Barbados (Wyllie et al., 2018), Canada (McIntyre, 2012; Rosenbloom and Meadowcroft, 2014; Mansouri Kouhestani et al., 2019), Costa Rica (Nandwani, 2006), Cuba (Prieto and Oliveira, 2018; Morales Pedraza, 2019), Dominican Republic (Guidi, 1993), El Salvador (Ambiente, 2005), Guadeloupe (Boland, 2015; Lauret et al., 2015), Guatemala (Orozco, 1987), Haiti (Oates et al., 2003), Honduras (El Blog del BID, 2018), Jamaica (Chen et al., 1994), Mexico (Hernández-Escobedo et al., 2015; Villicaña-Ortiz et al., 2015), Nicaragua (Ranaboldo et al., 2015), Panama (Becker, 1987), Puerto Rico (Figueroa-Acevedo and Irizarry-Rivera, 2014; Harmsen et al., 2014), Trinidad and Tobago (Boretti and Al-Zubaidy, 2019), USA (Jeppesen, 2004; Kodysh et al., 2013; Majumdar and Pasqualetti, 2019).

It is observed from Table 10 that the US, Mexico, and Canada were the top three solar energy installers (solar PV and CSP) in 2022, with total installed capacities of 113.1 GW, 9.0 GW, and 4.4 GW, respectively. The same ranking pattern holds for the solar PV category, with the US leading the continent at 111.5 GW (98.6% of its total solar capacity), followed by Mexico (9.0 GW, 99.8% of its total solar capacity) and Canada (4.4 GW, 100.0% of its total solar capacity). In the case of CSP installers in 2022, the US and Mexico were the only two countries in the continent with installed CSP capacities of 1.5 GW and 0.02 GW, respectively.

5.5. South America

Table 11 presents the solar capacity in South America at the end of 2022 (IRENA, 2023), along with studies assessing the solar energy potential of countries and territories in the continent. These assessments mark the initial steps toward solar energy development in the region. In the South American Continent, Argentina (Arboit et al., 2008; Sarmiento et al., 2019), Bolivia (Torrez et al., 2013), Brazil (Tiba et al., 2002; Martins et al., 2008; Cronemberger et al., 2012), Chile (Araya-Muñoz et al., 2014; Escobar et al., 2015), Colombia (Carvajal-Romo et al., 2019; López et al., 2020), Ecuador (Polit et al., 2016; Echegaray-Aveiga et al., 2018), French Guiana (Linguet and Atif, 2014; Albarelo et al., 2015), Paraguay (Becker Pessolani, 2016; Lindstrom et al., 2019), Peru (Horn, 2006), Suriname (Rolfe, 2015), Uruguay (Suárez et al., 2012; Abal et al., 2016), Venezuela (Ledanois and Prieto, 1988; Posso et al., 2014).

It is seen from Table 11 that Brazil, Chile, and Argentina were the top three South American solar energy installers (solar PV and CSP) in 2022, with total installed capacities of 24.1 GW, 6.2 GW, and 1.1 GW, respectively. The same ranking pattern applies to the solar PV category, with Chile being the only country in South America with a CSP capacity of 108 MW.

Table 11
South America installed capacity.

Country	CSP Capacity (MW)	PV Capacity (MW)	Reference
Argentina	-	1 104	(Arboit et al., 2008; Sarmiento et al., 2019)
Bolivia	-	170	(Torrez et al., 2013)
Brazil	-	24079	(Tiba et al., 2002; Martins et al., 2008; Cronemberger et al., 2012)
Chile	108	6 142	(Araya-Muñoz et al., 2014; Escobar et al., 2015)
Colombia	-	457	(Carvajal-Romo et al., 2019; López et al., 2020)
Ecuador	-	29	(Polit et al., 2016; Echegaray-Aveiga et al., 2018)
Falkland Islands	-	-	-
French Guiana	-	55	(Linguet and Atif, 2014; Albarelo et al., 2015)
Guyana	-	8	-
Paraguay	-	-	(Becker Pessolani, 2016; Lindstrom et al., 2019)
Peru	-	332	(Horn, 2006)
Suriname	-	12	(Rolfe, 2015)
Uruguay	-	270	(Suárez et al., 2012; Abal et al., 2016)
Venezuela	-	5	(Ledanois and Prieto, 1988; Posso et al., 2014)

Table 12
Oceania installed capacity.

Country	CSP Capacity (MW)	PV Capacity (MW)	Reference
American Samoa	-	5	-
Australia	3	26789	(Clifton and Boruff, 2010; Bahadori and Nwaoha, 2013; Prasad et al., 2017)
Christmas Island	-	-	-
Cocos Islands	-	-	-
Cook Islands	-	6	(Nikolic et al., 2016)
Fiji	-	9	(Prasad, 2013; Prasad and Raturi, 2020)
French Polynesia	-	46	(Thomaz and Michalson, 2014)
Guam	-	105	-
Kiribati	-	3	(Mala et al., 2008, 2009)
Marshall Islands	-	2	-
Micronesia	-	3	-
Nauru	-	3	-
New Caledonia	-	75	(Blanc et al., 2015)
New Zealand	-	303	(Kelly, 2011; Ahmad et al., 2015)
Niue	-	1	(Cole and Banks, 2017)
Norfolk Island	-	-	-
Northern Mariana Islands	-	-	-
Palau	-	4	-
Papua New Guinea	-	4	(Kaur and Segal, 2017)
Pitcairn	-	-	-
Samoa	-	14	(THOMSON, 1927)
Solomon Islands	-	4	(Vorrath, 2015)
Tokelau	-	1	(Watt and Passey, 2015)
Tonga	-	14	(Outhred et al., 2004; Weir, 2018)
Tuvalu	-	2	(Cole and Banks, 2017)
Vanuatu	-	5	(Walton and Ford, 2020)
Wallis & Futuna Islands	-	-	-

5.6. Oceania

Table 12 presents the solar capacity in Oceania at the end of 2022 (IRENA, 2023), along with studies assessing the solar energy potential of countries and territories in the continent. These assessments mark the initial steps toward solar energy development in the region. In Oceania, Australia (Clifton and Boruff, 2010; Bahadori and Nwaoha, 2013; Prasad et al., 2017), Cook Islands (Nikolic et al., 2016), Fiji (Prasad, 2013; Prasad and Raturi, 2020), French Polynesia (Thomaz and Michalson, 2014), Kiribati (Mala et al., 2008; Mala et al., 2009), New Caledonia (Blanc et al., 2015), New Zealand (Kelly, 2011; Ahmad et al., 2015), Niue (Cole and Banks, 2017), Papua New Guinea (Kaur and Segal, 2017), Samoa (THOMSON, 1927), Solomon Islands (Vorrath, 2015), Tokelau (Watt and Passey, 2015), Tonga (Outhred et al., 2004; Weir, 2018), Tuvalu (Cole and Banks, 2017), Vanuatu (Walton and Ford, 2020).

It is observed from Table 12 that Australia, New Zealand, and Guam were the top three Oceanian solar energy installers (solar PV and CSP) in 2022, with total installed capacities of 26.8 GW, 0.3 GW, and 0.1 GW, respectively. The same ranking pattern holds for the solar PV category, with Australia as the sole country in Oceania reporting an installed CSP capacity of 3 MW in 2022.

Academic research plays a crucial role in shaping a country's industry. This review paper focuses on the connection between academic solar energy research and its practical real-world implications. It examines the current state of solar power and related academic solar energy research in different countries, aiming to provide valuable guidance for researchers, designers, and policymakers interested in incorporating solar energy into their nation's electricity generation. This effort seeks to close the gap between research and practical implementation in the energy sector. Based on the presented Tables 7–12, it is seen that there are still 30 countries with no solar energy development among 235 countries (12.8%), collectively accounting for a total population of 44 million. The country names include Faroe Islands, Gibraltar, Liechtenstein, Monaco, and San Marino in Europe; Central African Republic, Djibouti, Equatorial Guinea, Lesotho, Saint Helena, São Tomé and Príncipe, and Western Sahara in Africa; Bhutan, Kyrgyzstan, Tajikistan, Timor Leste, and Turkmenistan in Asia; Bermuda, Dominica, Saint Barthelemy, Sint Maarten, and Saint Pierre & Miquelon in North-Central America; Falkland Islands, and Paraguay in South America; Christmas Island, Cocos Islands, Norfolk Island, Northern Mariana Islands, Pitcairn, and Wallis & Futuna Islands in Oceania. Twenty-three countries of the mentioned 30 countries, about 76.7%, have no reported academic solar energy research yet. Consequently, in seven countries (Djibouti and Lesotho in Africa; Bhutan, Kyrgyzstan, Tajikistan, and Turkmenistan in Asia; and Paraguay in South America), about 23.3%, there is solar energy research; however, there is still no observable solar energy development in these seven regions. Given the 2022 fossil fuel price crisis, there is an expectation that these 30 nations will adopt solar energy as an alternative to ensure their energy security in the near future.

6. Conclusion

The energy sector experienced a year of remarkable upheaval in 2022, possibly one of the most dramatic in many years. It began with lingering global supply chain difficulties stemming from the aftermath of the COVID-19 pandemic, compounded by decreased Russian gas exports to Europe due to the Ukraine crisis. This combination of factors escalated what was initially a significant worry into a complete fossil fuel price crisis, causing widespread repercussions across the globe. The fossil fuel price crisis in 2022 served as a clear indicator of the significant economic advantages that renewable energy can offer, particularly in enhancing energy security. In fact, 2022 marked a year when the energy security advantages of renewables were widely recognized once again.

During the past decades, solar technology has demonstrated a promising future among green energies. Through a detailed and systematic literature survey, the present review study summarizes the world solar energy status, including concentrating solar power and solar PV power, along with published solar energy potential assessment articles for 235 countries and territories as the first step toward developing solar energy in these regions. A comparison of the solar power status among countries and territories has been provided, considering their concentrated solar power and PV installed capacities for each continent. The literature survey reveals that clear gaps still exist in the field of solar energy. In the next three decades, the solar PV field can advance to become the second prominent generation source by constructing more solar farms, allowing countries to generate approximately 25% of the world's total electricity needs by 2050.

In comparison to the PV installations in 2018 (481 GW), the world's PV installed capacity is projected to increase almost six times by 2030 (to 2841 GW) and almost 18 times by 2050 (to 8519 GW). By 2050, Asia, led by China, is projected to dominate the solar PV market with around 57% of global PV installations, followed by North America (21%) and Europe (11%). The presented data indicates that the global weighted-average LCOE for solar PV technology was approximately 0.05 USD/kWh in 2022, projected to further decrease to a range of 0.014–0.05 USD/kWh by 2050. Currently, CSP technology has the highest LCOE at 0.118 USD/kWh among renewables. Still, this cost is expected to decrease in the coming years due to increased competition and lower installation prices in China. Finally, within the group of 235 countries, it's seen that 30 nations, comprising around 12.8% of the total, have yet to engage in solar energy development. These 30 countries collectively have a population of 44 million. Out of these 30 countries, 23 (approximately 76.7%) have not documented any academic research in the field of solar energy. Consequently, in the remaining seven countries, accounting for roughly 23.3% of the group, solar energy research is being conducted, but practical solar energy implementation remains absent up to the present moment. Due to the 2022 fossil fuel price crisis, an expectation arises that these 30 nations will adopt solar energy development as an alternative option to ensure their energy security in the near future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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