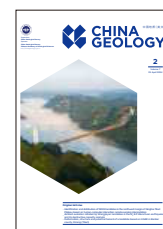




# China Geology

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## News and Highlights

### Carbon emission reduction: Contribution of photovoltaic power and practice in China

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As a clean and renewable form of energy, photovoltaic (PV) power generation converts solar energy into electrical energy, reducing the consumption of fossil fuels and significantly lowering greenhouse gas emissions. Amidst the global transition towards cleaner forms of energy, countries all around the world are vigorously developing PV technology. This endeavor spans from developed nations to emerging economies, with a proactive push for the layout and increased investment in the PV industry, which is thriving like bamboo shoots after a spring rain, continuously delivering new technological breakthroughs and innovative applications.

China, with its vast territory and wide distribution of solar resources, naturally possesses an advantage in developing the PV industry. Overall, China's solar energy resources are very abundant, albeit with notable regional variations, characterized by a higher concentration in the western regions compared to the central and eastern regions, and more in plateaus and arid areas with less rain, as opposed to flat and humid areas (Fig. 1). In 2023, the annual global horizontal irradiance was 1496.1 kWh/m<sup>2</sup>. Regions such as most of Tibet, central and northern Qinghai, and western Sichuan had an annual global horizontal irradiance exceeding 1750 kWh/m<sup>2</sup>, making them the richest in solar energy resources. Most of Xinjiang, most of Inner Mongolia, the central and western parts of the northwest region, most of North China, and the western part of the southwest region had an annual global horizontal irradiance between 1400 kWh/m<sup>2</sup> and 1750 kWh/m<sup>2</sup>, categorizing them as very rich in solar energy resources. Most of Northeast China, the eastern part of the

northwest region, central and eastern parts of Central China, most of East China, and South China had an annual global horizontal irradiance between 1050 kWh/m<sup>2</sup> and 1400 kWh/m<sup>2</sup>, categorizing them as rich in solar energy resources. The central and eastern parts of the southwest region and the western part of Central China had an annual global horizontal irradiance of less than 1050 kWh/m<sup>2</sup>, designating them as areas with general solar energy resources (Wind Energy and Solar Energy Center of China Meteorological Administration, 2024).

The technical potential of land centralized PV power in China is about 41.88×10<sup>9</sup> kW, and its spatial pattern is basically consistent with the spatial pattern of solar energy resource endowment. The “Three North” regions (Northeast, Northwest, and North China) account for 90.95% of the country's total, while the central and southeastern regions (Central China, East China, and South China) account for only 9.05%. For specific provinces, Xinjiang has the largest potential of centralized PV power, higher than 20×10<sup>9</sup> kW. The technical potential of distributed PV power in China is about 3.73×10<sup>9</sup> kW, with the “Three North” regions accounting for 51.34% of the national total, and the central and southeastern regions accounting for 48.66%. In terms of specific provinces, Shandong has the largest technical potential of distributed PV power, close to 400×10<sup>6</sup> kW (Wang Y et al., 2022).

According to the National Energy Administration, in 2023, China's newly added grid-connected PV power capacity was 216.3×10<sup>6</sup> kW, including 120.014×10<sup>6</sup> kW for centralized PV power stations and 96.286×10<sup>6</sup> kW for distributed PV power, among which the installed capacity of residential distributed PV reached 43.483×10<sup>6</sup> kW (Fig. 2). By the end of 2023, the accumulated grid-connected capacity reached a total of 608.92×10<sup>6</sup> kW, with centralized at 354.48×10<sup>6</sup> kW and distributed at 254.44×10<sup>6</sup> kW. According to data from the National Bureau of Statistics, in 2023, PV

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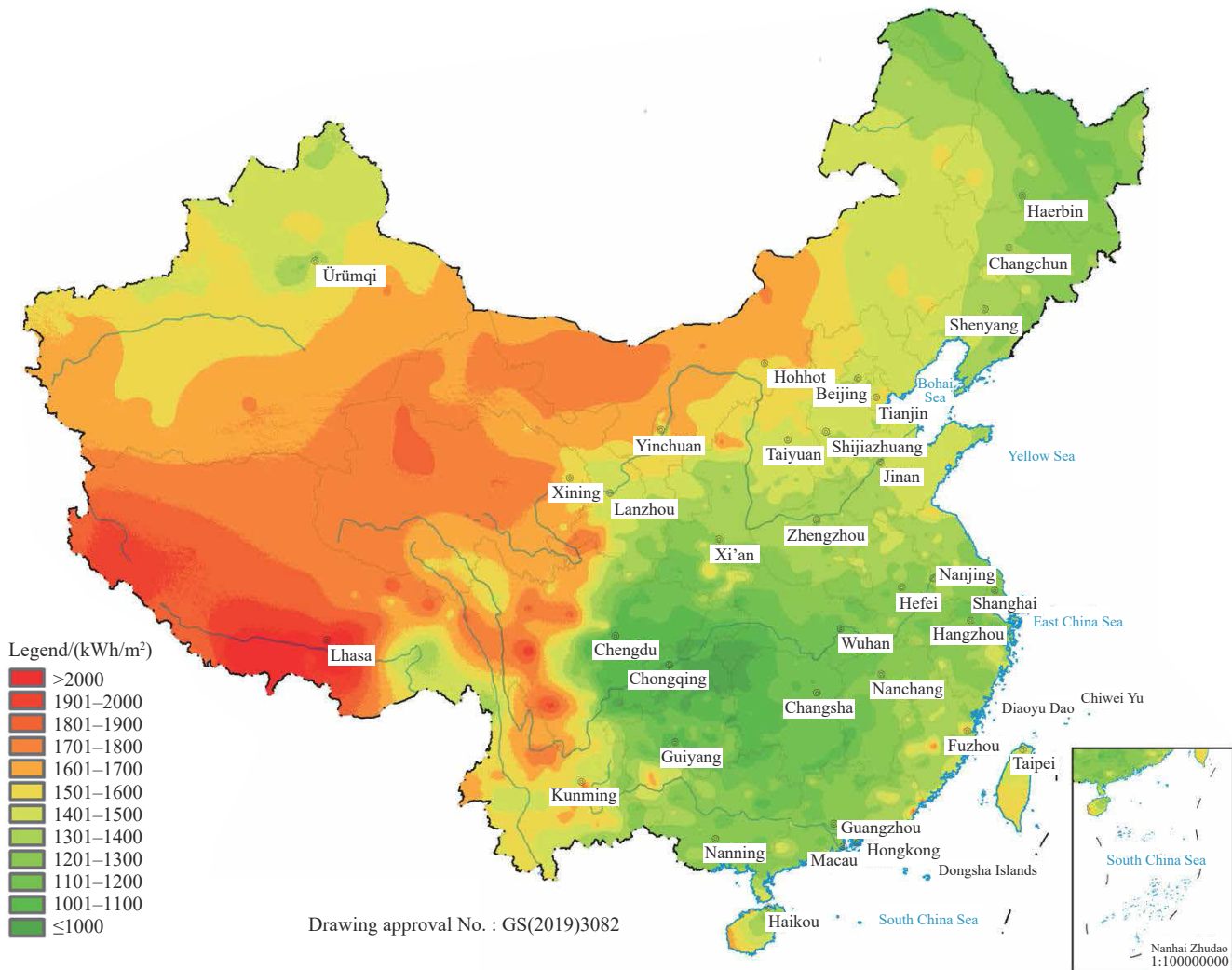
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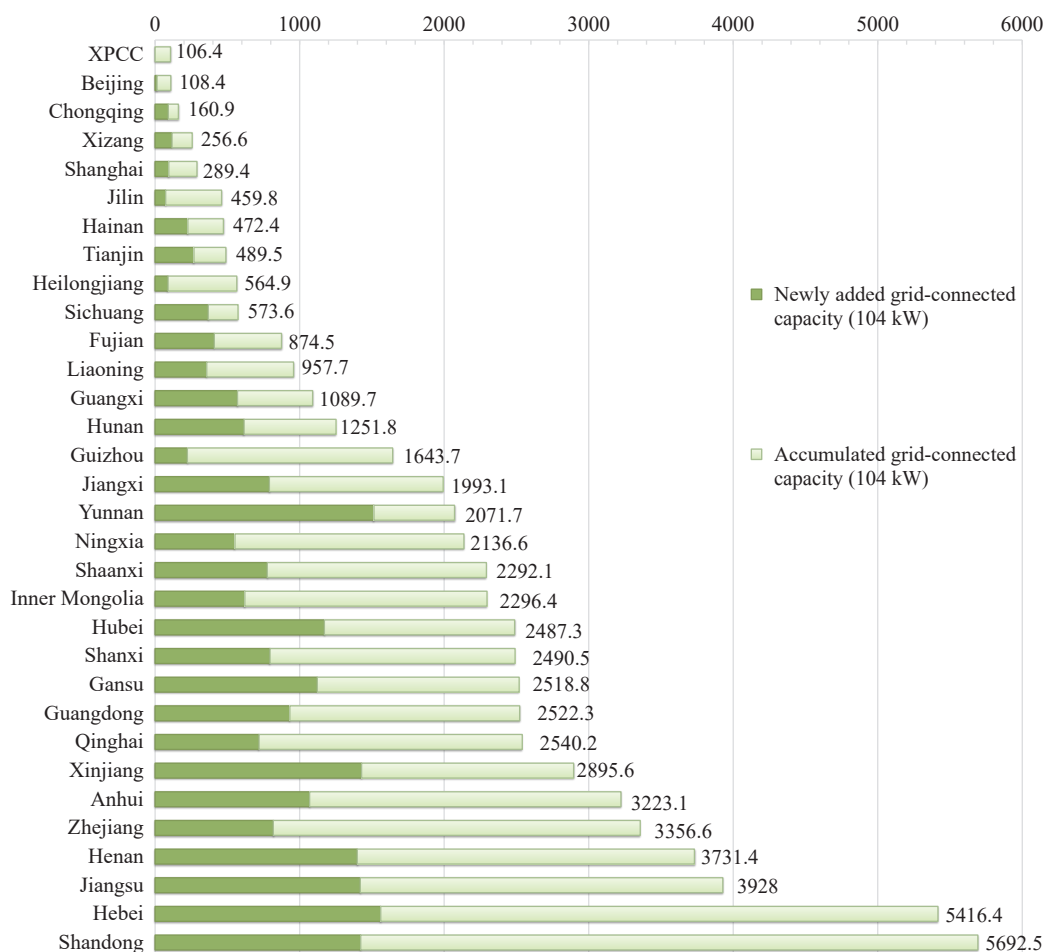
**Fig. 1.** Spatial distribution of the annual global horizontal irradiance across the land of China in 2023 (modified from Wind Energy and Solar Energy Center of China Meteorological Administration, 2024).

power generation for industrial enterprises above a designated size (with a main business income of more than  $2 \times 10^7$  yuan) totaled  $294 \times 10^9$  kWh, making a year-on-year increase of 17.2%. Overall, the PV power generation in 2023 was  $583.3 \times 10^9$  kWh, up by 36.4% compared to the previous year. Although the cumulative installed capacity of PV power has now surpassed hydropower and become the largest source of non-fossil fuel power generation, the accumulated grid-connected capacity only accounts for less than 2% of the technical potential as mentioned above, indicating that there is still significant room for improvement in the development of PV power generation in China.

Currently, China has established a complete PV industry chain that ranges from silicon material preparation to module production. This encompasses critical stages such as polysilicon production, silicon wafer manufacturing, cell production, and module packaging. The maturity of this industry chain is at the forefront globally. In recent years, the PV industry has seen significant improvements in cell efficiency through ongoing technological iteration and optimization. The application of PERC technology has become mainstream, greatly enhancing the efficiency of PV

cells. Additionally, new technologies such as TOPCon and HJT cells are also rapidly developing, promising further improvements in efficiency and cost-effectiveness for PV power generation. Moreover, Chinese PV companies are actively exploring and applying large-sized silicon wafers, multi-busbar designs, and bifacial cell technology to boost the output power of modules and reduce production costs. Due to technological innovation, mass production, and supportive policy, the cost of PV products in China continues to decrease, making PV power generation more competitive in the market. China has emerged as the world's largest producer of PV products with a huge production capacity and export volume. It accounts for more than 80% of the global manufacturing capacity for polysilicon, silicon wafers, cells, and modules, providing a substantial supply of efficient yet affordable PV products to the international market.

China is also actively exploring the integrated development of PV with other industries, forming a diversified development model of "PV +", which greatly promotes the diverse application and sustainable development of PV technology. The "PV + agriculture" model integrates PV power generation with agricultural practices by installing



**Fig. 2.** China's construction situation of PV power generation in 2023 (data from National Energy Administration, 2024). XPCC—Xinjiang Production and Construction Corps.

PV panels in farmland to realize dual land use benefits. The PV panels can provide shade for crops, reduce water evaporation, and generate the additional income generated from power generation. Furthermore, the “PV + desertification control” model utilizes panel shading effects to mitigate surface temperatures in arid areas like deserts and Gobi lands, curb wind erosion, and promote vegetation growth, thereby improving the ecological environment. The “PV + construction” model incorporates panels into building structures as part of the building materials, which not only provides clean energy but also enhances the aesthetics and environmental friendliness of the building. The “PV + transportation” model installs panels on highway slopes, service areas, tunnel entrances, and other transportation facilities, utilizing the idle space of these locations for power generation to provide green energy for the transportation system.

Amid the objectives of achieving carbon peak and carbon neutrality, China is actively engaged in the construction and planning of numerous large-scale wind and PV power bases (Fig. 3; Table 1). In the future, China's PV power generation is expected to experience exponential growth. Forecasts indicate that by 2030, the nation's cumulative installed PV capacity could range from  $840 \times 10^6$  kW to  $1260 \times 10^6$  kW, with a further anticipated expansion to  $2996 \times 10^6$  kW to  $3845 \times 10^6$

kW by 2060. Concurrently, the total electricity generation from PV power is projected to be between  $1.47 \times 10^{12}$  kWh and  $2.28 \times 10^{12}$  kWh by 2030, potentially surging to a range of  $3.11 \times 10^{12}$  kWh to  $6.00 \times 10^{12}$  kWh by the year 2060 (Institute for Carbon Neutrality, Tsinghua University, 2024). Capitalizing on the surging global demand for clean energy, China's PV sector is positioning itself as a cornerstone in the pivot towards a sustainable energy future. This strategic move is amplifying the sector's impact on the global fight against climate change and is instrumental in advancing sustainable development on a worldwide scale.

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**Fig. 3.** Photograph of PV (solar thermal) power station in Delinha City, Haixi Mongolian and Tibetan Autonomous Prefecture, Qinghai Province (after Zhang L, 2024).

**Table 1.** Overview of China's constructed and planned large-scale wind and solar power projects.

No.	Province	Project name	Construction scale/ $10^4$ kW			
			Wind power	PV power	Solar thermal	Total
1	Inner Mongolia	Mengxi Zhaoyi direct current outward transmission $4 \times 10^6$ kW wind and solar power project	380	20		400
2		Mengxi Tuoketuo outward transmission $2 \times 10^6$ kW wind and solar power project	170	30		200
3		Mengxi Kubuqi $2 \times 10^6$ kW PV desert control project		200		200
4		Mengzhong Ulanqab $1.2 \times 10^6$ kW wind power project	120			120
5		Ulanqab Jingda $1.5 \times 10^6$ kW integrated wind, solar, and storage large-scale wind and PV base project	120	30		150
6		Xilingol League ultra-high voltage outward transmission new energy phase III project	400	100		500
7		Chifeng $10^6$ kW wind, solar and storage base project	85	15		100
8		Bayannur Urad Front Banner Suji desert $2 \times 10^6$ kW PV desert control base project		200		200
9		Chifeng Hunshandake sandy land $10^6$ kW wind, solar and storage desert management new energy base demonstration project	80	20		100
10		Ordos Sulige integrated wind-solar-gas-hydrogen demonstration project	100	200		300
11		Mengxi Tuoketuo outward transmission phase II $1.5 \times 10^6$ kW PV desert control project		150		150
12		Mengdong Moqi wind power base project	60			60
13		Xilinhot $10^6$ kW new energy base project	50	50		100
14		Chifeng $2 \times 10^6$ kW self-regulated peak shaving capability wind, solar and storage multi-energy complementary integration + desert control base	150	50		200
15	Mengdong Yimu direct current outward transmission $10^6$ kW wind and solar project	80	20		100	
16	Qinghai	Hainan $3 \times 10^6$ kW PV power project		300		
17		Longfa Gonghe $10^6$ kW source-grid-load storage project	30	70		100
18		Fushan Gonghe $10^6$ kW source-grid-load storage project	30	70		100
19		Gonghe $10^6$ kW source-grid-load storage project		90	10	100
20		Gonghe $10^6$ kW PV-thermal project		90	10	100

Table 1 (Continued)

No.	Province	Project name	Construction scale/10 <sup>4</sup> kW			
			Wind power	PV power	Solar thermal	Total
21		Delingha 10 <sup>6</sup> kW PV-thermal project		80	20	100
22		Dachaidan 10 <sup>6</sup> kW wind-solar-storage project		30	70	100
23		Delingha 10 <sup>6</sup> kW source-grid-load storage project		30	70	100
24		Dachaidan 10 <sup>6</sup> kW source-grid-load storage project		100		100
25		Guide 10 <sup>6</sup> kW source-grid-load storage project	20	80		100
26		Zenan 10 <sup>6</sup> kW integrated PV-storage project		100		100
27		Guide 10 <sup>6</sup> kW source-grid-load storage project	20	80		100
28		Chaerhan industrial park 0.53×10 <sup>6</sup> kW source-grid-load storage project		53		53
29		Golmud 10 <sup>6</sup> kW wind-solar-gas-hydrogen project	50	50		100
30		Haixi 1.6×10 <sup>6</sup> kW PV-thermal project		150	10	160
31	Gansu	Hexi Wuwei Zhangye 1.5×10 <sup>6</sup> kW PV desert control project		150		150
32		Hexi Jiuquan 2.85×10 <sup>6</sup> kW wind-solar-thermal project	60	184	41	285
33		Hexi Jiuquan Jinta 10 <sup>6</sup> kW PV project		100		100
34		Changqing oilfield 0.53×10 <sup>6</sup> kW wind-solar integration base project	20	30		50
35		CNNC Gansu mining area clean energy base security project	60	40		100
36		Jinta County 1.6×10 <sup>6</sup> kW clean energy security project	90	70		160
37		Yumen 0.7×10 <sup>6</sup> kW PV-thermal-wind power hydrogen production demonstration project	40	20	10	70
38		Zhangye carbon neutrality base (phase I)	100	100		200
39		Wuwei Minqin County sand source new energy+comprehensive treatment project	20	80		100
40		Gansu Energy Chemical Investment Group Co., Ltd. 1.9×10 <sup>6</sup> kW PV power generation base project	0	190		190
41		Suzhou District 10 <sup>6</sup> kW source-grid-load storage integration project	0	100		100
42		Gansu Transportation Investment Management Co., Ltd. 10 <sup>6</sup> kW integrated wind-solar power project	60	40		100
43		Gansu Water Resources and Hydropower Survey and Design Research Institute Co., Ltd. 0.5×10 <sup>6</sup> kW PV power generation base project		50		50
44		Yili Group 0.5×10 <sup>6</sup> kW PV desert control project		50		50
45		Gansu Province Electric Power Investment Group Co., Ltd. 10 <sup>6</sup> kW integrated wind-solar power base	50	50		100
46		Lanzhou LS Group Co., Ltd. 0.5×10 <sup>6</sup> kW PV power generation base project		50		50
47		Gansu Construction Investment (Holdings) Group Co., Ltd. 10 <sup>6</sup> kW integrated wind-solar power base project	60	40		100
48		Hexi Jiugang 1.2×10 <sup>6</sup> kW wind-solar project	60	60		120
49	Shaanxi	Shaanxi-Wuwei direct current outward transmission phase I 6×10 <sup>6</sup> kW wind-solar project	205	395		600
50		Jinjie-Fugu outward transmission 3×10 <sup>6</sup> kW wind-solar project	80	220		300
51		Weinan 3.5×10 <sup>6</sup> kW wind-solar project	60	290		350
52	Ningxia	Ningxia Yindong direct current outward transmission 10 <sup>6</sup> kW PV project		100		100
53		Ningxia coal mining subsidence area 4×10 <sup>6</sup> kW PV project		400		400
54		Lingzhou-Shaoxing direct current outward transmission 2×10 <sup>6</sup> kW PV project		200		200
55	Xinjiang	Northern Xinjiang Urumqi 10 <sup>6</sup> kW wind-solar project	80	20		100
56		Changji Muxue 1.05×10 <sup>6</sup> kW wind-solar base project	80	25		105
57		Xinjiang kuqa 0.55×10 <sup>6</sup> kW PV project		55		55
58		Southern Xinjiang 2×10 <sup>6</sup> kW wind-solar project	40	160		200
59		Northern Xinjiang Shihezi 10 <sup>6</sup> kW PV project		100		100
60	Hebei	Zhangjiakou Yu County outward transmission 10 <sup>6</sup> kW wind-solar project	20	80		100
61		Zhangjiakou power plant new energy base project	40	60		100
62		Yu County power plant base (phase II) project	20	115		135
63		Yaoting County 10 <sup>6</sup> kW aquaculture-solar complementary + storage + hydrogen production comprehensive demonstration project		100		100
64		Yaoting County 10 <sup>6</sup> kW PV base project		100		100
65		Caofeidian petrochemical industrial base green low-carbon energy 1.5×10 <sup>6</sup> kW PV power generation project		150		150
66		Chengde Fengning wind-solar-hydrogen storage 10 <sup>6</sup> kW wind-solar project	30	70		100

**Table 1 (Continued)**

No.	Province	Project name	Construction scale/10 <sup>4</sup> kW			
			Wind power	PV power	Solar thermal	Total
67	Shanxi	Yuncheng 10 <sup>6</sup> kW wind-solar project	20	80		100
68		Pingshuo 0.6×10 <sup>6</sup> kW off-grid renewable energy hydrogen production project		60		60
69		Jinzhong 10 <sup>6</sup> kW wind-solar project	10	90		100
70	Shandong	Lubei 2×10 <sup>6</sup> kW PV project		200		200
71		Binzhou new energy PV power generation project		85		85
72		Huiyang phase IV 0.75×10 <sup>6</sup> kW PV project		75		75
73		Huiyang phase V 0.9×10 <sup>6</sup> kW PV project		90		90
74		Contemporary Amperex Technology Co. Limited 1.1×10 <sup>6</sup> kW aquaculture-solar complementary national large-scale PV power generation base project		110		110
75	Guizhou	Bijie 1.5×10 <sup>6</sup> kW PV project		150		150
76		Qiannan 1.5×10 <sup>6</sup> kW PV project		150		150
77	Guangxi	Hongshui river 1.4×10 <sup>6</sup> kW PV project		140		140
78		Hengzhou 2.6×10 <sup>6</sup> kW wind-solar project	39	221		260
79		Chongzuo 2×10 <sup>6</sup> kW wind-solar project	25.5	174.5		200
80	Anhui	Fuyang 1.2×10 <sup>6</sup> kW wind-solar project	55	65		120
81	Hunan	Loudi ecological management 10 <sup>6</sup> kW PV project		100		100
82	Jiangsu	Rudong million kilowatts level haishan PV project		190		190
83		Tianwan million kilowatts level offshore PV project		200		200
84		Pei County 1.05×10 <sup>6</sup> kW coal mining subsidence area ecological management clean energy base		105		105
85	Jilin	Lugu direct current outward transmission 1.4×10 <sup>6</sup> kW wind-solar-thermal project	80	40	20	140

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