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Concentrating Solar Thermal Power in China: 2025 Review and Outlook

Benjamin Lynch[1]
Department of Mechanical and Industrial Engineering,
Northeastern University,
Boston, MA 02115
e-mail: lynch.be@northeastern.edu

Hameed Metghalchi
Department of Mechanical and Industrial Engineering,
Northeastern University,
Boston, MA 02115
e-mail: m.metghalchi@northeastern.edu

Yiannis Levendis
Department of Mechanical and Industrial Engineering,
Northeastern University,
Boston, MA 02115
e-mail: y.levendis@northeastern.edu

China has become a global leader in the development of concentrating solar thermal power (CSP), taking advantage of state support, localized supply chains, and integration within hybrid renewable energy bases. By mid-2025, China's installed CSP capacity reached 1.14 GW, with a pipeline exceeding 8 GW across the provinces of Qinghai, Gansu, Inner Mongolia, and Xinjiang. Recent policy frameworks, including the 14th Five-Year Plan and the 2025 Energy Law, elevate CSP alongside photovoltaics and wind by mandating long-duration thermal storage and performance-linked incentives. Analysis of operational projects demonstrates CSP's strategic role in grid stability, enabling peak-shaving up to 80%, ramp rates of 3–6%/min, and synchronous inertia—capabilities not supplied by short-duration batteries. China's CSP supply chain is now over 90% localized for critical components and targets annual production equivalent to 5 GW annually, though challenges remain regarding workforce readiness and deployment in remote desert regions. While installed capacity has lagged earlier targets, CSP is increasingly valued for reducing renewable curtailment and displacing coal peaking units. If even half of the announced projects are realized, China could surpass Spain as the world's largest CSP market by 2030. This trajectory underscores both opportunities and risks: cost reductions through economies of scale and hybridization, alongside talent shortages and financing constraints. The findings provide context for policymakers and researchers evaluating CSP's role as a complementary, dispatchable solar resource within China's energy transition. [DOI: 10.1115/1.4070013]

Keywords: renewable energy, solar energy, solar thermal power, sustainability, thermal energy storage

Concentrating Solar Thermal Power Market and Development

2010–2014 Review. China's concentrating solar thermal power (CSP) industry is still in its infancy, but has undergone rapid evolution over the past 15 years. Amid the global trend toward more widespread adoption of renewable energy technologies, CSP has come to occupy a niche—albeit pivotal—role in China's expanding renewable energy portfolio. The early 2010s witnessed the development of several foundational CSP endeavors, taking the form of small-scale pilot projects. The earliest project to come online was the Badaling Dahan 1 MW tower in 2012—the first university-led demonstration plant in China [1–3]. Additionally in 2012, the IEE-CAS Yanqing 1 MW Experimental Solar Tower Plant in Beijing [2] marked the first step into solar tower and parabolic trough technology [3]. The SUPCON SOLAR Delingha 10 MW CSP plant in Qinghai was commissioned in 2013 [3]. The purpose of these projects was to gain operational experience across China's diverse geographical and climatic conditions (Fig. 1).

China's 13th Five-Year Plan (2016–2020) marked the country's formal government engagement with CSP technology, launching a variety of national demonstration projects [4]. Starting in 2016, the Shouhang Dunhuang 10 MW molten salt tower was the first commercial-scale project designed and connected to the grid in Gansu Province, with 15 h of molten salt heat storage and over 5000 h of annual power generation [5]. By the end of 2016, China had a cumulative installed CSP capacity of 23 MW [3].

2018 stands as a major breakthrough year for capacity additions, with several notable projects coming online: The Zhangjiakou No. 1 15 MW Linear Fresnel CSP plant (May 2018), the Delingha 50 MW Thermal Oil Parabolic Trough CSP Plant (Oct. 2018), the Shouhang Hi-Tech Dunhuang 100 MW MS Solar Tower Plant (Dec. 2018), and the SUPCON SOLAR Delingha 50 MW Solar Tower Plant in Qinghai (Dec. 2018). By the end of 2018, the cumulative installed capacity had jumped to 238 MW—a tenfold increase from 2016 [3].

In 2019, four more 50 MW plants came online under the national demonstration demo program: the PowerChina Gonghe 50 MW tower in Qinghai (Sept. 2019) [6], the Luneng Haixi Golmud

[1]Corresponding author.
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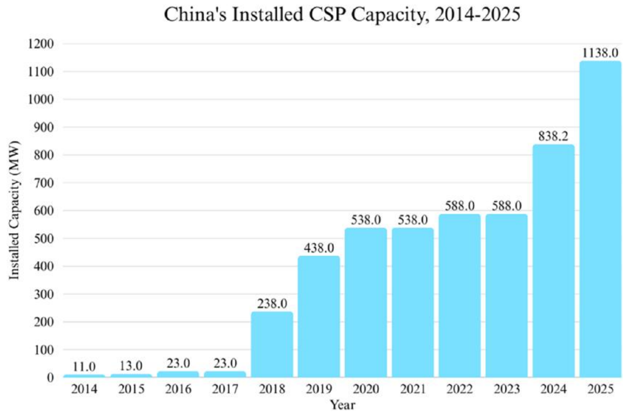

Fig. 1 China's installed CSP capacity, 2014–2025

50 MW tower in Qinghai (Sept. 2019) [7], the Energy China Hami 50 MW tower in Xinjiang (Dec. 2019) [8], and the Lanzhou Dacheng Dunhuang 50 MW Fresnel plant in Gansu (Dec. 2019) [9]. In addition to reaching a cumulative installed capacity of 438 MW, the Hami plant incorporated Schlaich Bergermann Partner's heliostat—a foreign technology developed in Germany [8]. In Jan. 2020, the China Southern Nuclear Power (CSNP) Urat 100 MW Thermal Oil Parabolic Trough CSP Plant was completed, marking the end of the exploratory demonstration phase and pushing the total installed capacity to 538 MW [10].

The period between 2020 and 2023 saw a lull in the development and installation of CSP plants across China. This was not due to failure of the technology, but rather a combination of factors, including the start of the COVID-19 pandemic impacting the supply chain as well as policy shifts described in the section "CSP Policy Landscape." A smaller experimental 50 MW tower—the Yumen Xinnen 50 MW tower in Gansu—brought the total installed capacity to 588 MW through 2023 [11].

The renewable-energy and modern-energy plans—a subsection of China's "14th Five-Year Plan" published in Mar. 2021—documented the specific inclusion of long-duration thermal energy storage (TES) and solar thermal power generation, suggesting building these projects and integrating them with both wind and photovoltaic bases. After the period of halted progress, CSP saw a resurgence in development in 2024 to support the national renewable energy plan, including multiple large-scale projects: The China National Nuclear Corporation (CNNC) Yumen 100 MW Fresnel plant [12] (built-in into a large system including 200 MW wind and 400 MW photovoltaic sources) is under construction as Sept. 2024 [13]. Similarly, the Akesai Huidong 110 MW tower was built in Gansu as of Dec. 2024 [14] as a subsection of a 750 MW hybrid park [15]. A smaller plant, the Tibet Zabuye 40 MW trough, was fully put into operation in May 2025 [16] with the renewed assistance of Germany's Schlaich Bergermann Partner—the first exposure of the Tibetan Plateau area to CSP technology [17]. These additions brought the total installed CSP capacity to approximately 838 MW by the end of 2024.

Although not a major addition to installed capacity in 2024, China claimed to be the first to demonstrate a next-generation technology in the field of supercritical carbon dioxide (sCO_2) solar thermal power generation with an experimental 0.2 MW pilot power cycle in Yanqing [18].

2025 Outlook. According to the China Solar Thermal Alliance's (CSTA's) *Blue Book of China's Concentrating Solar Power Industry 2024*, there are 34 reported ongoing CSP projects across various provinces and autonomous regions, with an estimated installed capacity of 3300 MW. Solar tower projects account for 22 of those projects, representing approximately 71% of the total pipeline. Additionally, linear Fresnel and trough plants fill a niche, comprising less than 25% of the total capacity, with a remaining 250 MW left to an unspecified configuration of CSP—likely R&D pilot plants in the realm of sCO_2 and adjacent technologies [3].

The *Blue Book of China's Concentrating Solar Power Industry 2024* cites an additional 37 planned CSP projects, with an estimated installed capacity of 4750–4800 MW. Of the 37 specified, 31 of them have a stated CSP rating, and 81% of them are determined to be power tower configurations—the remaining 19% are made up of parabolic trough and unspecified/hybrid systems, with many unspecified configurations likely to be solar tower projects. A summary of the in-progress and anticipated projects (agnostic of province or autonomous region) is provided in Table 1, highlighting the preference of tower systems over others.

In summary of current and future plans, three distinct geographic hubs have been identified for CSP development. Qinghai remains the CSP heartland with approximately 1.6 GW of molten salt tower orders centered on Golmud, Gonghe, and Dachaidan. Inner Mongolia follows with at least 1.2 GW rated, and an additional 0.5 GW planned. These are to be embedded within the Ulanbuhe, Ordos, and Tengger "wind-photovoltaic (PV)-storage" export bases. Lastly, the Xinjiang–Tibet frontier is projected to host approximately 1.4 GW of combined capacity.

Molten salt towers continue to dominate, comprising 52 of the 65 rated projects, with nearly every new tower specifying 6–10 h of thermal energy storage; a stance that positions CSP as the long-duration storage component within many desert-based hybrid bases.

Global Context and Variable Renewable Energy Landscape. What began in 2010 with a global capacity of approximately 1.2 GW—led mostly by parabolic trough plants in Spain and the US—has since increased to a capacity of 7–8 GW worldwide. China now ranks among the top four countries in installed CSP capacity and is poised to see the largest development pipeline of new projects across the world. As of 2020, China had approximately 0.54 GW of installed capacity, representing about 8% of global CSP deployment at that time. With recent additions, the share rose to approximately 10% by 2024.

As noted in the section "2025 Outlook," China's development pipeline surpasses that of other countries, comprising 65 CSP projects either under development or in advanced planning. By contrast, the Middle East and North Africa (MENA) region had only one major project underway early 2024—the 100 MW Redstone tower in South Africa [19,20]. Morocco's 150 MW Noor Midelt hybrid CSP plant has faced delays and remains on hold as the Moroccan government addresses concerns regarding CSP technology and project financing [20].

Across Europe, only Italy has commissioned a minor 4 MW Fresnel plant, while Spain has achieved limited progress in further CSP development [21,22]. That said, if China successfully realizes even half of its ongoing and planned projects, it will likely become the world's largest CSP-operating country by 2030, besting Spain's currently leading 2.3 GW of installed power [22].

As of Apr. 2025, China's combined wind and solar capacity reached 1482 GW generating over one-quarter of the country's electricity—surpassing the 1451 GW of coal- and gas-fired units and thereby exceeding the fossil fuel-based sources. The solar capacity alone occupied 1080 GW of the total 1482 GW mentioned, with about 92 GW of new PV systems installed in May 2025 [23].

Including the new Xinjiang 100 MW linear Fresnel Plant, the Jinta ZhongGuang 100 MW CSP block, and the Three Gorges Renewables 100 MW CSP tower in the Qinghai Province, China's total installed CSP power now reaches an estimated 1.138 GW [24–26]. Although CSP currently accounts for less than 0.05% of China's electricity, it continues to play a niche role as a dispatchable, heat-stored solar power source—especially

Table 1 Analysis of Blue Book of China's CSP industry 2024 in-progress and combined CSP projects

Metric	In-progress	Anticipated	Combined
Projects with specified CSP power	34	31 (of 37)	65
Declared CSP MW	3300 MW	4650 MW	7950 MW
MW "TBD"	0	6	≥600 MW once fixed
Dominant technology	22 towers	30 towers	52 towers—6700 MW
Other technologies	Troughs: 5 (400 MW) Fresnel: 3 (300 MW) Unspecified: 4 (250 MW)	Troughs: 1 (TBD) Unspecified: 6 (200 MW)	Troughs: 6 (400 MW) Fresnel: 3 (300 MW) Unspecified: 10 (450 MW)
Power tower share	71% of MW	94% of MW	∼84% of declared MW

when paired with photovoltaic and wind sources in hybrid configurations [27].

Concentrating Solar Thermal Power Policy Landscape

The policies governing China's implementation and approach toward CSP serve as the primary demand signal—while China's installed CSP capacity is tiny relative to their photovoltaic and wind capacity, the purpose of the policy is to increase its targets for grid strengthening and reliability, rather than the sheer quantity of megawatt-hours.

National Mandates and Directives (State Council, NDRC, and NEA). China's Energy Law came into effect from Jan. 1, 2025. This serves as the first unified framework for governing China's entire energy sector, while also explicitly including solar thermal power in the same level of recognition as photovoltaics—establishing a statutory mandate to actively develop this area of technology [28]. This formal recognition of CSP has elevated it to a strategic priority, alongside a nationwide acknowledgement of China's "dual control system" aiming to further promote clean and low-carbon energy development while reducing reliance on fossil fuels [28].

The Energy Law is reinforced by the *Opinions on Accelerating the Comprehensive Green Transformation of Economic and Social Development*, which were released by the Central Committee of the Chinese Communist Party (CCP) and the State Council on July 1, 2024. This was a historic milestone in China's call to systematically accelerate the country's green energy transformation, outlining macroeconomic sustainability targets—including a mandate for China's environmental protection industry reaching ¥15 trillion, and for non-fossil energy usage must comprise 25% of total energy consumption by 2030 [27].

Further downstream, China's National Energy Administration published the *Notice on Promoting the Large-scale Development of Solar Thermal Power*, issued in Mar. 2023. This notice, discussed in China's *Blue Book of China's Concentrating Solar Power Industry 2023*, emphasized the importance of integrating CSP with photovoltaic and wind farms to stabilize renewable energy output as well as setting the standard for CSP projects to meet or exceed the technical performance levels of prior demonstration plants. In addition to defining CSP's role in peak shaving, it instructed provinces to adopt standardized frameworks for project financing, land allocation, and pricing, with local energy authorities being tasked with reserving and coordinating CSP plants within existing renewable energy bases [29].

The 2022 *New Energy Implementation Plan,* co-issued by the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA), cited solar thermal power as a part of a complementary spread to the rising photovoltaic and wind share. It explicitly discussed pilot demonstrations of combined wind–solar–thermal storage across Inner Mongolia, Qinghai, Gansu, and Xinjiang—all regions designated for large-scale hybrid renewable energy bases [27].

Finally, China's 2021 *Carbon Peak Action Plan*, published by the State Council, helped to lay the groundwork for CSP as the grid-stabilizing technology it is seen as today—embedding it within China's path toward carbon peaking by 2030. The plan also specifically called for CSP to be deployed within large-scale renewable energy bases [30].

Five-Year Plans Affecting Concentrating Solar Thermal Power. China's *12th Five-Year Plan of Renewable Energy Development* (2011–2015) saw the earliest mention of CSP technology. This era was the precursor to CSP gained more formal traction under the *13th Five-Year Plan,* but nonetheless marked the turning point in China's broader clean energy transition. It highlighted the promise of CSP as an emerging technology for medium-to-long-term energy storage, and proposed validation and demonstration as the first steps—all supported by government-backed R&D efforts [31].

The *13th Five-Year Plan* (2016–2020) marked the first time CSP was formally integrated into China's national energy approach, displaying a significant shift in how the technology was prioritized. The NEA set an ambitious target, seeking to deploy 5 GW of CSP capacity by 2020. To jumpstart this, 20 demonstration projects (for a total of ∼1.35 GW) were approved across the regions of Gansu, Qinghai, and Inner Mongolia. Despite the ¥1.15/kWh feed-in-tariff (FiT) designated for this batch [32,33] only ∼538 MW of CSP installations were achieved (∼11% achievement)—a considerable shortfall due to a lack of planned financing and an underestimation of the timelines needed to develop these systems [33]. Still, these lessons helped to better shape the 14th Five-Year Plan, which defined better policy refinements and therefore a better-prepared approach to CSP integration.

The *14th Five-Year Plan* (2021–2025) reframed CSP from a technology pilot to a core asset for grid reliability. Additionally, the CSP outlook shifted from trying to hit a capacity target, and instead toward a vision of CSP in the context of hybrid bases—combinations of photovoltaic, wind, and CSP systems in solar-rich western regions of Gansu, Inner Mongolia, and Qinghai. The *Notice on Promoting Large-Scale Development of Solar Thermal Power* set the directive of striving to achieve 3 GW per year of CSP construction across the duration of the 14th Five-Year Plan. This same notice also granted preferential status to CSP hybrid plant construction, with temporary allocations of 800 MW in Inner Mongolia, 700 MW in Gansu, and 1 GW in Qinghai, 100 MW in Ningxia, and 200 MW in Xinjiang [34].

Provincial Regulations and Implementation: Qinghai Province. China's CSP ambitions have shifted from national to targeted provincial initiatives—particularly in western and northeastern regions, where solar resources are more abundant. The 2023 [29] and 2024 [3] Blue Books illustrate this shift from central government planning to more region-specific deployment, speaking specifically to hybrid installments amongst their desert bases as well as their carbon peaking agendas.

As CSP has emerged as a national technological priority, Qinghai has become the leading province for CSP deployment. Its 2023 policy mandates that the capacity ratio of photovoltaics

Table 2 Common provincial trends

Policy lever	Common threshold	Variants
TES hours	≥6 h	Ningxia ≥ 8 h; Gansu hybrid hydrogen pilots may rise to 10 h
PV: CSP ratio	6:1	Inner Mongolia requires 200 MW minimum—not a ratio
Tariff regime	After FiTs, tariffs are now pegged by coal power prices or pilot rules	Qinghai has fixed ¥0.55/kWh; Gansu coal-benchmark + VAT rebate
Land—use and Environmental, Social, and Governance (ESG)	Proof of non-arable, corridor-free desert siting	Gansu and Qinghai require formal clearance for environmental corridors
Local-content rules	60–70% must be locally sourced (steel structures, drive systems)	Inner Mongolia gives extra bid points to projects with ≥70% in-province fabrication

to CSP must not exceed 6:1, alongside a specification for minimum thermal storage requirement of 6 h/day—2190 h annually. Additional provisions require that projects meet strict performance criteria for TES uptime, grid compatibility, and peak-shaving capability—in return, these plants are granted preference to dispatch rights as well as access to market-based electricity pricing. By 2024, Qinghai had integrated CSP into multiple hybrid base development plans. From the perspective of economic incentives, a ¥0.55/kWh feed-in-tariff for 2024–2028 [3,35], alongside allowing CSP to participate in ancillary services markets, which enables CSP projects to earn extra revenue streams beyond selling electricity.

Provincial Regulations and Implementation: Gansu Province. Gansu's 2023 carbon peaking action plan aimed to integrate CSP into its broader industrial transformation, emphasizing the role of molten salt TES systems in electricity generation, industrial process heat, and green hydrogen production. Across the 2023 and 2024 Blue Books, several reserved projects (the CNNC Rich Energy's 100 MW CSP system in Jinta and the 100 MW CSP component of the China General Nuclear Power Groups (CGN's) 700 MW hybrid plant in Yumen) show to be a part of the push to expand renewables past power generation. Gansu is actively promoting pilot studies to optimize CSP-based steam production as a heat source for alkaline electrolysis. Since Gansu projects no longer receive a special feed-in-tariff, they are now compensated at the coal-benchmark price ¥0.308/kWh, as well as a 50% value-added tax (VAT) rebate under the Western-Region tax regime.

Provincial Regulations and Implementation: Inner Mongolia. Inner Mongolia is to focus on integrating CSP into its hybrid energy base model. Under the NEA's Mar. 2023 policy, Inner Mongolia committed to contributing significantly to China's 3 GW per year of CSP additions for the duration of the 14th Five-Year plan. Furthermore, the Urat Middle Banner hybrid base—which includes a 100 MW molten salt tower—is currently under construction. Regional planners have adopted performance-linked land allocation models to ensure that CSP installations meet solar field size and TES duration requirements consistent with national guidelines.

The 2024 rules followed closely with Qinghai's CSP standards, but raised the scale by specifying ≥ 200 MW CSP blocks and ≥6 h TES in all hybrid energy bases [36].

Provincial Regulations and Implementation: Xinjiang Province. While Xinjiang is among the most favorable regions in China for solar resource utilization, it has progressed more slowly than other regions engaging with the development of CSP. Challenging terrain, geographic remoteness, and investment constraints have been primary barriers to CSP construction. The role of CSP within Xinjiang is expected to grow and is included in the transformation blueprint within the 2024 Blue Book, although logistical and financial constraints—particularly delays in ultra-high-voltage transmission infrastructure—have hindered development.

In all, the provincial-level CSP development had seen a defined step of maturity into more diverse and performance-driven ecosystem aligned with national goals—summarized in Table 2. Qinghai and Gansu lead in terms of policy innovation and deployment; Inner Mongolia is scaling rapidly as well with the new tender rules, while Xinjiang—despite having ideal solar conditions—remains constrained by general infrastructure and market access limitations. This provincial engagement helps to underpin China's national strategy in attempting to deploy 3 GW of CSP annually under the 14th Five-Year Plan, while also helping to firm the grid and advance the use of CSP for more flexible processes. This overall direction of travel indicates efforts to codify minimum scale, storage, and performance metrics and replace the one-off demo FiTs with more performance-accountable and cost-competitive CSPs.

Planned Versus Actual Concentrating Solar Thermal Power Deployment. Since 2012, China has consistently fallen short on the ambitious goals it has set for itself: 1 GW by 2015 [37], 5 GW by 2020 [38], and a high-reaching 3 GW per year aspiration outlined in the 14th Five-Year Plan [39]. This repeated shortcoming prompted China to pivot from simple megawatt targets to the strategic use of CSP in hybrid energy systems.

Although China initially set targets of 1 GW by 2015 and 3–5 GW by 2020, its actual cumulative capacity in 2015 was just under 14 MW—representing approximately 1.5% of the original target. At that time, China was still operating at a pilot scale and had not yet initiated its batch of 20 national demonstration plants called for in the NEA's *Notice on the Construction of CSP Demonstration Projects* in 2016 [40].

The 13th Five-Year Plan (2016–2020) solar goal officially included the target of seeking 5 GW of CSP by 2020 while also introducing the 20 initial demonstration projects. To help catalyze these 20 projects (totaling 1.35 GW), a feed-in-tariff of ¥1.15/kWh was administered. Tight completion deadlines, which were repeatedly extended, resulted in an actual operational capacity of approximately 545 MW from 12 CSP plants—a realization of only 10–11% in comparison to the 5 GW target [41].

A stagnation period occurred between 2021 and 2023, with no net capacity additions in 2021 and only 50 MW added in 2022. By the end of 2023, the installed capacity remained at 588 MW with no new project connections to the grid. Subsequently, the 2024 Blue Book reported a cumulative installed capacity of 838 MW—an increase of approximately 250 MW over 2023—and approximately 8 GW combined of both under construction and planned development—marking the first significant post-demonstration capacity increase [3].

The persistent underachievement of CSP capacity relative to China's targets has prompted a shift away from rigid megawatt quotes toward qualitative mandates discussing grid support, storage hours, and hybridization. Although installed capacity increased by nearly 42% from 2023 to the end of 2024, the trend

Table 3 Supply chain structure overview

Tier	Function	Entities
Tier 0	National/Provincial Governance	• National Energy Administration (NEA) • National Development and Reform Commission (NDRC) • Qinghai and Inner Mongolia Development and Reform Commission (Provincial DRCs)
Tier 1	Engineering, Procurement, and Construction; System Integrators	• Beijing Shouhang High-Tech Energy Technology Co. • Cosin Solar Technology Co. • Northwest Engineering Corporation (PowerChina) • SEPCOIII Electric Power Construction Co. • Hengji Nengmai New Energy Technology Co. (SunSum)
Tier 2	Technology and Subsystem Providers	• TRX Solar Technology Co. • Royal Tech • Beijing TeraSolar Photothermal Technologies Co. • Lanzhou Dacheng New Energy
Tier 3	Raw Materials and Components	• Gansu Kaisheng Daming Solar Energy Technology Co. • Shanxi Wojin • Jiangsu Feiyue Pump Co. • Shenzhen Enesoon Science & Technology Co. • TOPFM (Shanghai) Automation Instrument Co.

continues, suggesting a 2030 scenario range between single-digit gigawatt levels and high-ambition pathways approaching 30 GW. Nonetheless, future growth in China's CSP sector will depend on its ability to demonstrate clearer economic and grid-stabilizing advantages.

Supply Chain and Workforce

Supply Chain Mapping Introduction. China's CSP supply chain has emerged as one of the most vertically integrated and domestically driven in the world, with estimates of over 85% localization achieved across core CSP components based on in-depth CSP Blue Book analysis of capacity and firm structure. This section explores the tiered structure of China's CSP supply chain to subsystem assembly and integration, with high-level examples shown in Table 3.

The structure described in the CSTA Blue Books emphasizes vertical integration to minimize reliance on imports while expediting CSP deployment at a mass scale. This strategy also supports China's cost-reduction efforts by enabling project development within regional industrial hubs.

Glass and Reflective Mirrors. China's mirror supply exceeds 30 million m^2/year [3], positioning itself to satisfy domestic demand as well as opening the possibility of export potential with other CSP markets. Kaisheng Daming (Gansu—700 tons per day of ultra-white glass; 2 GW equivalent per year), Chengdu Change (Sichuan), and Baichuan Solar (Inner Mongolia) are companies focused on producing high-reflectivity mirrors, both parabolic and flat for CSP applications. Wuhan Sunnpo Solar (Hubei) alone produces up to 800 MW/year across a variety of mirror types [3].

Vacuum Receiver Tubes. Vacuum receiver tubes play a critical role in converting concentrated solar flux into usable heat; as such, China has prioritized near-complete domestic production. TRX Solar (Beijing) leads with 800,000 tubes per year [3], followed by Royal Tech (Zhejiang) produces 320,000 per year [3]. The combined national output reaches approximately 2 million units per year, supported by a collective eight manufacturers spread throughout Shandong, Hebei, and Inner Mongolia.

Thermal Energy Storage Salts. China's nitrate and molten salt production surpasses 1.9 million tons per year, including sodium nitrate, potassium nitrate, and other mixed salt blends [3]. Shanxi Wojin (Shanxi), Winghai Salt Lake (Qinghai), Enesoon (Shandong), and Shandong Aobo (Shandong) are key producers in this mix, and are all firms capable of supplying CSP-grade purity materials for a target 6–15 h of thermal storage configurations.

High-Temperature Pipes and Alloys. Stainless and nickel-alloy piping required for power blocks, receiver loops, and molten salt transport is produced in quantities exceeding 25,000 tons annually [3]. Sinosteel (Jiangsu), Changzhou Shenneng (Jiangsu), and Jiangsu Xinchang (Jiangsu) are primary producers in this area, with all materials specified to withstand sustained exposure to the 550–750 °C benchmark.

Pumps, Valves, and Flowmeters. A fully localized branch of China's CSP value chain—Feiyue Pump (Jiangsu) and Huawei Pump (Shandong) support over 1000 units per year of molten salt pump systems [3]. Shanghai Yahe Valve (Shanghai) and Zhejiang High Pressure Valve (Zhejiang) are responsible for producing over 7000 units annually [3], while Shanghai TOPFM is the sole designated producer of high-temperature flowmeters, representing an instrumental chokepoint.

Geographic Clustering Trends. In the analysis of China's CSP supply chain, three industrial clusters can be identified. The Northwest Deployment Belt, composed of Gansu, Qinghai, and Xinjiang, is a region home to field-scale deployment and construction of CSP plants. Opposite this is the East Coast Industrial Belt made up of Shandong, Jiangsu, and Zhejiang. This cluster is a high-density manufacturing hub focused on precision components of CSP systems (glass, sensors, valves, and steel). Lastly, an Innovation Corridor sits between Beijing and Tianjin, which houses TeraSolar and TRX Solar—primary R&D centers and high-tech companies (Table 4).

Supply Chain Strategic Takeaways. Five main points can be drawn from a high-level analysis of CSTA's Blue Books:

(1) China's supply chain ecosystem is likely above a 90% domestic production level [42] across all major subsystems, which is enabled by key industrial cluster regions. The self-sufficiency that emerges from this helps to ensure both cost stability and a rapid and compact procurement/deployment system. Additionally, this also reflects a deliberate industrial policy to achieve export-readiness.

(2) Component production now exceeds a theoretical 5 GW per year, indicating that China is overproducing with the likely intention of entering international markets. Cosin Solar and Shouhang (Tier 1 firms) have signaled intent to help develop projects in the MENA and Latin America regions.
(3) The consolidation of raw material extraction, component manufacturing, and deployment across three distinct “zone” helps to reduce logistics, minimize supply-side delays, while simultaneously fostering system-level integration—feeding into their desired “vertical integration” processes.
(4) While not an exhaustive list of Tier 2 and Tier 3 companies, a noticeable bottleneck in instrumentation, TES material testing, and commissioning expertise remains as a strategic vulnerabilities. While there is no bottleneck to deployment per se, these do affect long-term performance assurance and international standard alignment.
(5) Collaborative potential is extremely high, especially with regard to technical validation and advanced instrumentation. Technical exchange, co-testing, or bilateral development between the US Federally Funded Research and Development Centers (FFRDCs) could help to serve as third-party validators, especially when considering hybrid CSP configurations.

Workforce and Jobs. The current workforce size in China’s CSP industry can only be estimated. According to an estimate published in the China Solar Thermal Alliance’s 2022 Bluebook, an interview with the Executive Vice President of China Hydropower and Water Conservancy Planning and Development provided which estimated that approximately 440,000 enterprises provide services related to CSP and thermal energy storage [43]. This number encompasses small and micro-enterprises (in the Tier 3 supply chain realm)—of this number, an estimate of 500–600 companies operate within a specialized CSP segment, employing approximately 59,000 individuals—though this figure was reported in 2022, and has very likely grown since then [44]. By comparison, China’s photovoltaic industry employs approximately 2.46 million people, while the wind power sectors employ about 745,000, highlighting that CSP remains a niche employer, likely due to the technical skills gap [45].

Although not specific to China, the International Renewable Energy Agency (IRENA) estimates that a 100 MW CSP plant with 10 h of TES requires approximately 4640 full-time job-years during construction and manufacturing—offering significant potential for job creation [46]. An approximate labor breakdown of this is provided in Table 5.

Approximately 74% of labor requirements are associated with medium- and low-skilled manual work, which can be absorbed through vocational training programs, while the remaining 8% represent a small but essential need for experts in thermal, optical, and systems modeling [46].

Based on IRENA’s employment analysis (estimating 4640 job-years per 100 MW CSP plant), China’s annual target of 3 GW of CSP implies an estimated 139,000 job-years would be required annually for manufacturing and construction, assuming staggered project development. While these jobs would likely be temporary over a typical 2–3-year construction period, they would significantly boost regional employment. An additional 1500–2100 permanent positions would be required for operations, maintenance, administration, and security.

Geographic and Demographic Challenges. As previously noted, CSP resources and facilities are primarily concentrated in China’s western provinces of Qinghai, Gansu, Xinjiang, and Inner Mongolia—provinces that see the highest availability of solar irradiance and land. Baichuan Solar Thermal—a manufacturing company specializing in CSP power station integration—established a factory in Inner Mongolia at the end of 2022. In an interview with the deputy general manager, it was reported that 60% of the employees were front-line workers from other provinces, and there was a severe shortage of engineers skilled in system modeling and integration. The general manager further stated that China’s CSP industry is only about 30 years old, and the shortage of interdisciplinary talent remains evident. It was also noted that while photovoltaic and wind power majors are being developed quickly across vocational schools, CSP-focused curricula have not experienced the same institutional support or growth as photovoltaic and wind programs [47].

In contrast to the CSP plants concentrated in the west, high-end R&D centers and engineering talent are primarily located in China’s eastern urban regions—Beijing, Shanghai, Zhejiang, etc.—leading to an east–west talent gap. A 2021 article from *The Paper*, originating from the state-owned Shanghai United Media Group, highlights the difficulties that emerge from this gap. The talent gap has resulted in employers reporting individuals often performing multiple roles in the “new energy” sector, which encompasses solar, wind, hydrogen, biomass, and geothermal energy, and the practice of poaching is a common practice amongst companies dealing in the “New Energy” domain; an increase in wages typically follows [48].

From a socio-cultural perspective, the western provinces have been described as lagging in development. The remote mountainous areas fielding large photovoltaic/CSP/wind plants are located on “barren hills and slops, with no entertainment and limited social interaction,” [48] making it difficult to attract and retain young professionals willing to relocate from their hometowns, and so recruitment and retention of works across all skill levels have proven to be significant obstacles to CSP development.

Education and Training Pipeline. To help alleviate the talent shortages, China is concurrently developing an education and training ecosystem for CSP—covering vocational education, university programs, short courses, and in-house corporate training.

Karamay Vocational and Technical College launched the first CSP-specific diploma program in the country in 2014, in direct response scarcity of talent in the western region [49]. The program was developed through an industry–academia partnership with Xinjiang’s Shanfu New Energy Co. and focused primarily on conducting scientific research projects and teaching fundamental courses in thermodynamics, manufacturing, and electrical engineering to support the CSP training pipeline [49].

At the university level, CSP primarily draws upon core disciplines, such as mechanical, electrical, control, and materials engineering—similar to what is seen at the international level, but with the addition of a materials focus [50]. The Ministry of Education approved a new major titled New Energy Science and Engineering (NESE) in the late 2000s and early 2010s, covering solar, wind, biomass, geothermal, and other renewable forms of energy production. North China Electric Power University was among the first to integrate this major, and Shanghai Jiao Tong University followed by establishing a New Energy Institute, including CSP research within its domain [44]. According to a 2024–2024 ranking article out of Xi-an Jiaotong University’s State Key Laboratory of Multiphase Flow in Power Engineering, over 160 universities across China have established the New Energy Science & Engineering undergraduate program, indicating rapid expansion from the original handful [51]. A 2023 article from Guangdong University of Technology reports over 100 programs nationwide [52], corroborating both the trend and quantity of these emerging programs.

The NESE major typically covers both photovoltaic and wind energy generation, but only a small subset of universities offer dedicated courses on solar thermal power generation. Publicly available program descriptions indicate that several universities explicitly teach CSP within the NESE curriculum—often listed as “solar thermal power generation” or “solar thermal utilization.” The identified programs are summarized in Table 6.

In addition to university-level education, China’s Ministry of Education has contributed to the development of a nationally standardized and approved curriculum for a three-year “Solar Thermal Technology

Table 4 Production capacity of critical tier 2 companies within China

Component type	Enterprise	Production capacity/info
Ultra-white glass for CSP	Dalian Yaopi Glass Co.	- 700 tons per day - Annual production capacity: 2 GW - Glass thickness: 2–4 mm
	Henan Ancai Hi-Tech Co.	- 600 tons per day - Annual production capacity: 2.5 GW - Glass thickness: 3–15 mm
	Gansu Kaisheng Daming Solar Energy Technology	- 600 tons per day
	Fujian Ruibo Glass Co.	- 600 tons per day
Mirrors	Shandong Yuying Optical Instrument Co.	- Fresnel lenses of Polymethyl Methacrylate (PMMA), High-Density Polyethylene (HDPE), Polycarbonate (PC), Polyvinyl Chloride (PVC), Polystyrene (PS), tempered glass, and silicone; diameters between 3 mm and 2200 mm
	Zhaoqing Dexin Vacuum Equipment Co.	- New production line of solar concentration mirrors built
Reflective mirrors	Beijing TeraSolar Photothermal Technologies Co.	- Mirrors for linear Fresnel CSP plants: 5 Mm^2/year - Heliostat fields for linear Fresnel CSP plants: 3 Mm^2/year
	Chengdu Change New Energy Storage Technology Co.	- Mirrors for parabolic trough CSP plants: 3.5 Mm^2/year - Flat mirrors for CSP plants: 6 Mm^2/year
	Gansu Kaishen Daming Solar Energy Technology Co.	- Mirrors for parabolic trough CSP plants: 3.6 Mm^2/year - Flat mirrors for CSP plants: 10 Mm^2/year
	Lanzhou Dacheng Technology Co.	- Mirrors for linear Fresnel plants: 3 Mm^2/year - Secondary double parabolic mirrors: 500 K/year - Supply and construction capacity of linear Fresnel collector field equipment: 300 MW/year
	Inner Mongolia Baichuan Solar Technology Co.	- Mirrors for parabolic trough CSP plants: 3.5 Mm^2/year - Flat mirrors: 6.5 Mm^2/year
	Shouhang High-Tech Energy Technology Co.	- Mirrors for parabolic trough CSP plants: 2 Mm^2/year - Flat mirrors: 5.6 Mm^2/year
	Wuhan Sunnpo Solar Technology Co.	- 800 MW/year (various mirror types)
Vacuum receiver tubes	Beijing TRX Solar Technology Co.	- 800 K/year
	Royal Tech CSP Limited	- 320,000/year
	Lanzhou Dacheng Technology Co.	- 60,000/year
	Shandong Huiyin New Energy Technology Co.	- 200,000/year
	Hebei Daorong New Energy Technology Co.	- 200,000 medium–high-temperature vacuum receiver tubes
	Inner Mongolia Xuchen Energy Co.	- 200,000
	Shandong SIMED New Energy Technology Co.	- 100,000
	Shaanxi Baoguang Vacuum Electric Device Co.	- Annual production capacity of 4 m vacuum receiver tubes: 30,000 - Annual production capacity of 2 m vacuum receiver tubes: 60,000
High-temperature nickel-based alloy tubes	Changzhou Shenneng Metal Product Co.	- 1500 tons per year
Salt mixtures (nitrates)	Hubei Yuntu Molten Salt Technology Co.	- Sodium nitrate and sodium nitrite: 150,000 tons per year
	Jiangzi Jinlida Potassium Industry Co.	- Potassium nitrate: 100,000 tons per year
	Golden Potassium Technology Co.	- Potassium nitrate: 150,000 tons per year
	Qinghai Salt Lake Wojin Thermal Storage Technology Co.	- Molten salt-grade potassium nitrate and sodium nitrate: 400,000 tons per year
	Shanxi Wojin New Materials Co.	- Molten salt-grade potassium nitrate, sodium nitrate, calcium nitrate, and others: 140,000 tons per year
	Jiaocheng Country Bingsheng Chemical Co.	- Molten salt-grade potassium nitrate, sodium nitrate, and others: 40,000 tons per year
	Sinkiang Nitrate Minerals Co.	- Sodium nitrate: 70,000 tons per year
	Sociedad Quimica Y Minera De Chile S.A.	- Potassium nitrate and sodium nitrate: 300,000 tons per year
	Shandong Huayang Dr Chemical Industry Co.	- 270,000 tons of nitric acid plants, 100,000 tons of potassium nitrate and water-soluble fertilizer plants
	Shandong Enesoon New Material Technology Co.	- 300,000 tons of binary, ternary, and multicomponent molten salts
	Shandong Aobo Energy Storage Technology Co.	- Annual supply capacity of 120,000 tons of compound molten salts (potassium nitrate, sodium nitrate, sodium nitrite)
	Shandong Haihua Liwei New Materials Co.	- Annual production capacity of 100,000 tons of potassium nitrate, 20,000 tons of magnesium nitrate, and 200,000 tons of solar molten salt products
Thermal oil	Jiangsu Zhongnen Chemical Technology Co.	- 30,000 tons per year
		- 36,800 tons per year

Table 4 *Continued*

Component type	Enterprise	Production capacity/info
	Hebei Jindong Technology Group Co.	
Molten salt pumps	Jiangsu Feiyue Pump Co. Jinan Huawei Pump Co. Lanzhou Lanpump Co. PowerChina Shanghai Energy Equipment Co.	- >1000 molten salt pumps per year - 100 long-axis molten salt pumps per year - Production capacity of molten salt pumps - Molten salt pump engineering prototypes for 100 MW solar tower plant
Molten salt valves	Shanghai Yahe Valve Completion Co. Beijing Jiajie New Energy Saving Technology Co. Zheijiang High and Medium Pressure Valve Co. Chengdue Huaxi Fluid Control Technology Co.	- 7000 sets per year - 3000 sets per year - ~8000 tons production capacity - ~1000 annual capacity
Thermal insulation materials	Hubei Shuoli New Material Technology Co. Luyang Energy-Saving Materials Co.	- 25,000 tons - 500,000 tons
Stainless steel pipes	Changzhou Shenneng Metal Product Co. Jiangsu Xinchang Special Steel Pipe Co. Sinosteel Stainless Steel Pipe Technology Co. Shanghai Feiting Pipe Manufacture Co.	- 10,000 tons - 35,000 tons per year - 10,000 tons per year - 12,000 tons of various material fittings - 7200 tons of flanges
Speed reducers	Hengfengtai Precision Machinery Co.	- 200,000 sets per year
Molten salt electric heaters	Hangzhou Runpaq Energy Equipment Co. Zhejiang Green Storage Technology Co. Xi'an Huijin Technology Co.	- 2000 MW/year - 2000 MW - 1 GW
Molten salt flowmeters	Shanghai Topfm Technology Development Co.	- 500 sets per year

Note: These entities and values are obtained directly from China's 2024 Blue Book [3].

and Applications" course. All six programs (Table 7) follow similar course structures as outlined in the official Teaching Standards for Solar Thermal Technology and Applications document [59].

Strategic Outlook. In summary, China's CSP sector is set for significant growth over the next decade, driven largely by the National Energy Administration's target of 3 GW per year under the 14th Five-Year Plan. This scale-up could generate over 100,000 job-years annually through the construction of outlined projects, alongside thousands more long-term operational roles. The industry also offers key strategic industrial benefits toward China's Belt and Road initiative, opening Chinese firms for export

Table 5 Labor breakdown of a 100 MW CSP plant with 10 h of TES

Stage	Key roles	Share of labor
R&D and design	- System modeling - Optical design - Thermal simulations - Advanced materials	~8% (composed mainly of highly skilled engineers)
Manufacturing	- Reflector/glass production - Absorber tubes - Molten salt tanks - Receivers - Drive systems	~43% (medium-skill workers)
Engineering, procurement, and construction	- Civil works - Heliostat field construction - Mechanical/Electrical installation	~35% (heavy reliance on manual/skilled trades)
Operations and maintenance	- Plant operation and control room staff/ engineers - Field technicians - Cleaning teams - Safety specialists	~14% (between 50 and 70 jobs estimated for a 100 MW plant)

Table 6 Example CSP university-level programs in China

University/Program	Evidence of CSP content
Beijing Information Science & Technology University (BISTU)	BISTU's NESE shows its main courses, including *Solar Energy Conversion Principles and Technology, Solar Thermal Power Generation System Engineering, Distributed Photovoltaic System Engineering Design,* and *Solar Energy Utilization Technology*, illustrating that CSP system design is taught in tandem with photovoltaic and wind courses [53].
Xi'an University of Technology (XUT)	XUT describes its NESE program similarly, with another main course explicitly listing *Solar Thermal Power Generation* along with wind turbine design, photovoltaic power generation, and energy-storage principles [54].
Changsha University of Science & Technology (CSUST)	CSUST's NESE program helps to train students in mastering principles of wind and solar power generation, storage, and multi-energy complementary systems, with a core course including *Solar Thermal Utilization Principles and Applications* [55].
Beijing Institute of Petrochemical Technology (BIPT)	BIPT's NESE program implements a research-oriented approach, listing *Solar Energy Utilization Technology* in its research directions [56].
Anhui University of Technology (AHUT)	AHUT's NESE program was amongst the earliest approved, with professional courses such as *Solar Energy Utilization Introduction* and *Renewable Energy Generation Technology* [57].

opportunities following investments in high-temperature materials, molten salt systems, and advanced receivers. Additionally, the majority of CSP projects are in relatively underdeveloped western Chinese provinces, which will serve to drive local employment rates.

Several workforce challenges could potentially hinder this momentum, with a critical shortage of skilled engineers trained in high-level systems engineering, thermal storage, and project execution necessary for CSP design. University programs produce a low—but quickly growing—amount of CSP specialists, though seemingly still too few to meet the growing demand. To compound this problem, remote-site locations pose additional difficulties—likely requiring better housing, transport, and other forms of social infrastructure to reduce turnover and raise incentives for outside talent.

Grid Integration and Concentrating Solar Thermal Power Value

Concentrating Solar Thermal Power Impact: Grid Stability, Renewable Curtailment, and Collocation Benefits. The most recent insights into CSP's role in enhancing grid stability come from the China Solar Thermal Alliance 2024 Blue Book. These findings specifically address peak shaving—the ability to reduce grid demand during peak hours by supplying stored energy from renewable sources. Among eight commercial demonstration plants, a peak-shaving depth of up to 80% was recorded, with ramp rates of 3–6% of rated power per minute and cold/hot start times of approximately 1 h and 25 min, respectively [3]. It was further noted that CSP generators can contribute to load balancing, enabling the replacement of traditional coal-fired units [3].

Research from Tsinghua University [60] compared the performance of a power grid using only photovoltaic and wind sources to one incorporating photovoltaic, wind, and CSP. Their studies showed that with 22 GW of photovoltaic power and 7 GW of wind power installed, the Qinghai power grid could supply uninterrupted clean power for three consecutive days during the flooding season. However, with an additional 4 GW of CSP capacity, this duration increases from 3 to 30 consecutive days, highlighting the niche role that cannot be fulfilled by traditional 4–6-hour battery storage [3].

In the same 2022 study from the Rocky Mountain Institute (RMI) and Tsinghua University, a near-zero-carbon Qinghai grid scenario for 2030 was modeled. By simulating a projected 3 GW of CSP with 12–14 h of thermal energy storage, wind curtailment was reduced from 6.8% to 6.2%, and photovoltaic curtailment from 9.2% to 8.8%, respectively—greater than what batteries or hydrogen power could offer under the same conditions [60].

In contrast to renewable energy technologies, such as PV, hydrogen, and battery storage—which primarily offer short-duration discharge or involve high capital costs—CSP can also support China's grid through ancillary services. CSP's synchronous steam turbines provide rotational inertia, voltage regulation, and fault ride-through capabilities, enabling grid frequency stabilization and support for black-start operations following outages [3].

Collectively, these operational and system-level benefits reinforce CSP's strategic importance within China's hybrid energy bases in the western provinces. As reliance on variable solar and wind energy increases, CSP serves both as a backup generation source and as a foundation for dispatchable, clean, and stable power.

Concentrating Solar Thermal Power Cost Trends (LCOE)

China Versus Global Concentrating Solar Thermal Power Project Costs. The first round of CSP demonstration projects in China consisted mainly of 50–100 MW trough and tower plants

Table 7 Example CSP vocational programs in China

Institution	Evidence of CSP content
Shanxi Water Conservancy Vocational and Technical College Guangdong Maoming Preschool Teachers College Xi'an Aviation Vocational and Technical College Jiuquan Vocational and Technical College Qinghai Architectural Vocational and Technical College Qinghai Qaidam Vocational and Technical College	All six listed vocational schools are expected to offer the three-year Solar Thermal Technology and Applications program beginning in 2025 [58].

built between 2018 and 2021. In an effort to induce further financial support, these plants benefited from a fixed FiT of ¥1.15/kWh for 20 years. The 2018 50 MW CGN Delingha parabolic trough plant, located in Qinghai, cost approximately $292 million and had a reported levelized cost of energy (LCOE) of $0.13/kWh [61]. Similarly, the 100 MW CSNP Urat parabolic trough plant in Inner Mongolia cost around $421 million USD and achieved an LCOE of $0.10/kWh [62].

Over time, China's CSP LCOEs have fallen, with more recent projects benefiting from cheaper domestic equipment and lower financing costs. The Akesai "beam-down" tower and PV hybrid project in Gansu receives an FiT remuneration of ¥0.31/kWh—about 30% of the original demonstration FiT [63]. Similarly, Qinghai province introduced a provincial FiT of ¥0.55/kWh for projects approved between 2024 and 2028 [3].

The 2024 CSP Blue Book outlines the multi-stage cost-reduction roadmap. The demonstration stage of projects during the 13th Five-Year Plan had assumed investment costs of ¥32,000/kW with an FiT scheme of ¥1.15/kWh. Larger projects (300 MW with 10 h of TES) would see a reduced investment to ¥14,000/kW and an FiT scheme of ¥0.48/kWh, and post-2025 1 GW projects could achieve a potential of ¥11,000/kW and tariffs of ¥0.35/kWh [3]. These policies shape an LCOE gradient, wherein projects in high-resource provinces (Gansu and Qinghai) see lower tariffs, whereas earlier demonstration projects (Inner Mongolia and Xinjiang) had to rely more on the ¥1.15/kWh FiT scheme.

Global CSP benchmarks have also seen a significant decline in LCOE. IRENA reports that between 2010 and 2022, the global weighted average LCOE for newly commissioned CSP projects decreased from $0.38/kWh to $0.118/kWh—around a 70% overall decline. There are several major global comparators:

- Spain pioneered commercial CSP systems with a feed-in-tariff system. Royal Decree 661 (2007) offered two possible remuneration options: a fixed €0.27/kWh for the first 25 years (and €21.5 following) or a premium of €0.254/kWh on top of the market price [64]. The tariffs helped to drive a rapid growth of ~2.3 GW worth of trough CSP plants, but the government canceled the FiT in 2012, replacing it with a "reasonable profitability" regime, halting new projects [65].
- The United Arab Emirates (UAE) hosts Dubai's 700 MW Noor Energy 1, which combines 600 MW trough, 100 MW tower, and 250 MW of photovoltaics with about 5907 MWh of thermal storage. The Dubai Electricity and Water Authority awarded the project with a record low tariff of $0.073/kWh, and the total project cost was listed at $4.4 billion [66].
- Morocco's Noor II plant is a 200 MW parabolic trough CSP system commissioned in 2018 and has achieved an LCOE of $0.16/kWh for a project cost of $1.119 billion [67].
- South Africa's 100 MW Redstone tower plant, featuring 12 h of molten salt TES, cost $704 million with an LCOE of $0.13 USD/kWh, while being supported by South Africa's Renewable Energy Independent Power Producer Procurement Program [68].
- The United States' Crescent Dunes 110 MW tower plant, located in Nevada, cost $1.032 billion and signed a 25-year Power Purchase Agreement (PPA) at $0.14/kWh. The LCOE is estimated to be $0.18/kWh [69].

Early Chinese projects were competitive with the US and Moroccan plants. Recent Chinese tower projects with provincial tariffs around ¥0.55/kWh start to approach the cost of Dubai's hybrid project. The global best-in-class LCOEs remain lower than average Chinese LCOEs, primarily due to cheaper financing and larger project scales.

Key Cost-Reduction Drivers. China's CSP cost reductions stem primarily from two areas: its domestically driven supply chain and its policy, finance, and market approach.

China's 2024 Blue Book outlines a detailed supply chain, including all of the necessary subcomponents and manufactured materials for CSP systems. By 2024, many core components—heliostats, receivers, heat exchangers, and related equipment—were domestically produced, reducing equipment costs [3]. A previous 2019 NREL study determined that Chinese trough plants have site improvement costs less than half of the default System Advisor Model defaults ($12.59/m^2 versus $30/m^2) and thermal storage costs approximately one-third of U.S. reference values ($22/kWh$_{th}$ versus $75/kWh$_{th}$) [70]. While this is largely beneficial to China's CSP development ecosystem, higher project and land management costs are still a barrier due to a variety of taxes and fees; a 25% income tax is applied for government investment authority-verified projects, but could receive exemptions in the first three years and a 50% reduction in years four through six. Additionally, the VAT fell from 17% to 16% in 2018 [70].

The 2023 Blue Book provided insight into the benefits of economies of scale with CSP tower plants, demonstrating that scaling a tower plant from 100 MW to 300 MW with 10-hour TES lowers the LCOE from ¥0.8487/kWh to ¥0.6981/kWh—an almost 18% reduction [29]. Further 2026 estimates show that taking advantage of the economies of scale, coupled with O&M optimization, could reduce tower LCOEs to ¥0.5597–0.5623/kWh by 2026, and potentially further to ¥0.5287–5312/kWh with advanced molten salts [29].

FiTs and provincial pilot programs helped to initiate the financial competitiveness of CSP plants—notably, the guaranteed fixed FiT of ¥1.15/kWh for 20 years for the first 20 demonstration projects. Projects approved after 2023 are required to participate in competitive tendering or provincial schemes [29]. Additionally, early projects also relied on low-interest, long-term loans from a variety of sources. The Delingha trough plant was financed with a $150 million Asian Development Bank (ADB) loan, a $78.6 million Export–Import Bank loan, and $96.7 million in equity. The ADB loan was afforded a 20-year term with below-market interest rates, aiding in reducing the LCOE to ~$0.13/kWh [71].

China's encouragement of source-grid-load-storage bases in remote provinces reaps both technical and financial benefits. Hybrid CSP + PV projects (e.g., the Jinta 100 MW CSP + 600 MW PV project) share grid infrastructure—Cosin Solar also reports that the plant's total investment of ¥4.2 billion covered both CSP and PV, with the CSP portion including 9-hour storage [72].

Summary and Outlook

China's entry into CSP has moved from a handful of exploratory and experimental pilots in the early 2010s, to the world's largest pipeline of CSP projects. Following nearly a decade of experimentation, the 13th Five-Year Plan established 20 demonstration plants under a generous feed-in-tariff scheme, with an installed capacity target of 5 GW by 2020. Although only 538 MW was delivered, the experience ultimately contributed to essential technical know-how and the development of a domestic supply chain. The introduction of the 14th Five-Year plan shifted the focus from flat capacity quotas to a more comprehensive approach, with emphasis on integration of CSP within "source-grid-load-storage" bases in provinces like Qinghai, Gansu, and Inner Mongolia. These provinces have begun to embed CSP alongside gigawatt-scale solar and wind projects, with minimum specified storage durations between 6 h and 10 h and performance-linked land allocations. As of 2025, China has installed about 0.94 GW of CSP, but has a combined 65 projects either under construction or in planning, totaling approximately 8 GW of capacity. CSP towers dominate this pipeline, accounting for nearly 84% of the total capacity.

China's main competitive advantage is derived from an industrial strategy aimed at self-sufficiency and scale. Domestic enterprises provide over 90% of CSP components, from ultra-white glass and heliostats to vacuum receiver tubes and molten salts. Annual production capacity now exceeds 5 GW, indicating that China is preparing not only for its domestic development pipeline, but also for participation in export markets. Provincial policies have stepped in to replace feed-in-tariff schemes with performance-linked tariffs tied to coal prices, mandatory storage hours, as well as tendering rules that reward local content. This framework has already helped to drive down project costs: demonstration plants started by receiving ¥1.15/kWh, while more recent hybrid projects have secured tariffs around ¥0.55/kWh. The Blue Book roadmap suggests that costs are expected to decline further toward the ¥0.35–0.50/kWh range for larger (≥300 MW) tower projects, which approach the current world-leading Dubai hybrid project. Collectively, these developments demonstrate how China's vertical integration and economies of scale are directly contributing to capital expenditure reductions.

While a promising trajectory, China has repeatedly fallen short of its ambitious targets—1 GW by 2015, 5 GW by 2020, and 3 GW per year under the 14th Five-Year Plan—mostly due to financing bottlenecks, construction delays, and shifting policy priorities. Additionally, workforce readiness remains another constraint, with the CSP workforce dwarfed in comparison to China's PV and wind energy sectors and a reported shortage of highly skilled engineers responsible for system-integration-level knowledge. An unwillingness of workers to move to remote desert plants undermines the otherwise forward momentum in China's CSP sector development.

Looking forward, China's current trajectory implies that CSP will remain a niche, but strategically critical component of the overall energy mix. If even half of the announced projects are realized, China will surpass Spain to become the world's largest CSP market by 2030. The overall pivot toward hybrid plants embedded in desert renewable energy bases aligns directly with China's 2030 carbon peaking goal by providing multi-day flexibility, reduced wind and solar curtailment, and assisting in displacing coal-fired peaking units. Further cost reductions will depend on scaling tower blocks to the 300–500 MW range, furthering deployment of next-generation receivers (especially utilizing sCO_2 plants), and maintaining provincial incentives that are aligned with long-duration storage and ancillary-service markets. Persistent labor shortages, remote-site challenges, and the growing competitive tendering environment mean that the CSP capacity may grow more slowly than official targets suggest.

For US institutions such as the National Renewable Energy Laboratory and the Department of Energy, China's experience stands to offer both lessons as well as opportunities for collaboration. Benchmarking Chinese supply chain strategies could help US projects reduce balance-of-plant and thermal storage costs, whereas joint research on advanced materials, heliostat metrology and calibration, and sCO_2 cycles—research activities already seen ongoing at the US institutions—could address shared technical challenges [73–75]. The US laboratories could provide another source of independent validation of Chinese component performance and share expertise in instrumentation and control—key bottlenecks in China. Joint participation in international standard-setting or codes for CSP plants, as well as reciprocal pilot projects in both countries, could accelerate learning curves while building a more robust global-focused market. These opportunities align with a broader body of research on integrating CSP with advanced cycles and alternative fuels, such as recompression Brayton systems, solar tri-generation, and e-fuels [73–78]. Lastly, workforce development partnerships—joint training programs or exchange fellowships—could help to fill engineering gaps on both sides while keeping CSP on its trend of being a viable complement to photovoltaics, wind, and battery storage. Through this lens, CSP is unlikely to displace cheaper renewables, but its ability to provide a dispatchable, thermal-stored form of solar power and ancillary services makes it a vital component to a robust and resilient carbon-free grid.

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Conflict of Interest

There are no conflicts of interest.

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No data, models, or code were generated or used for this article.

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