Chapter 7
Summing Up

CSP is a dispatchable renewable electricity technology which might contribute substantially to a sustainable energy transition everywhere, in tandem with an increasing penetration of variable renewable energy technologies. According to the IEA [8], it could represent as much as 11% of electricity generation in 2050, with 954 GW of installed capacity (up from 5 GW today). CSP has a main distinguishing feature compared to other renewable energy technologies: It is able to provide dispatchable electricity, which allows balancing intermittent renewable electricity sources if these achieve a high penetration in the future. CSP plants contribute to grid balancing, spinning reserve, and ancillary services. They can also shift generation to when the sun is not shining and/or maximize generation at peak demand times [14]. However, with a current share in electricity generation worldwide of 0.1% [12], the technology currently plays a minor role in the power mixes everywhere.

With respect to the rest of renewable energy technologies, the future prospects of CSP generation depend on several factors: the evolution of the generation costs of CSP and the alternative renewable energy technologies (which, in turn, is highly influenced by capital costs and, to a lesser extent, the annual expenditures on O&M), grid infrastructure investment requirements for the transmission of the electricity from the production to the consumption areas, the evolution of the costs of storing electricity at large scale, the valuation and demand of dispatchability in electricity systems and/or in policy support frameworks.[1] To start with, the most pertinent comparison is with the cost of PV generation [2, 4: 378–386 and 1004, 6: 831 and 841, 9: 17]. A few years ago, both PV and CSP required considerable regulatory support in order to ensure their economic feasibility [10]. Furthermore, the cost of the PV kWh was twice the cost of the CSP kWh. However, after the drastic reduction of the price of panels between 2008 and 2012, the situation has totally reversed. In the middle of the last decade, the cost of PV was above \$0.3/kWh [11], whereas the cost of CSP was around \$0.2/kWh (see Chap. 3). However, in 2016, some PPAs for CSP were signed

[1] Another important use of CSP to be considered is desalination.

P. Mir-Artigues et al., *The Economics and Policy of Concentrating Solar Power Generation*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-11938-6_7

at $0.12/kWh. An auction in Dubai in 2017 (led by the Dubai Electricity and Water Authority) awarded CSP capacity at $0.073/kWh, and an auction in South Australia in that same year awarded capacity at $0.06/kWh for a 150 MW solar tower to be erected near Port Augusta [7, 9].[2] It should be taken into account that those locations have good conditions in terms of DNI (more so in the case of South Australia) and access to good harbor and road infrastructures, which facilitate the transport of equipment to the plant location (not far from the consumption areas). When it comes to PV, one of the last 2017 tenders in Germany—which is not precisely a sunny country—resulted in prices for utility-scale photovoltaic that ranged between €0.0429/kWh ($0.0505/kWh) and €0.0506/kWh ($0.0595/kWh). In early 2018, submitted bids reached an average value of €0.0433/kWh ($0.0527/kWh), with the lowest bid of €0.0386/kWh ($0.047/kWh) [5].[3]

On the other hand, advances in the design and cost reduction of batteries and other electricity storage options erode the strongest comparative advantage of CSP with respect to variable renewable sources: its dispatchability. Authors like [3] envisage considerable reductions in the price of lithium-ion batteries, both for electric cars and static storage: from $1000/kWh in 2010 to $162/kWh in 2017, and a prediction of $74/kWh for 2030. Taking these figures into consideration, the learning ratio, or the price decrease for every doubling of productive capacity, could be set at 19% [9].

Taking into account the above-mentioned considerations and assuming that there will be a need for flexibility (particularly with higher shares of variable renewables), the future widespread deployment of CSP may be contingent upon (1) the level of transmission costs and (2) the cost of other electricity storage solutions. Therefore, the condition for the widespread diffusion of CSP generation (MWh) can be expressed with the following conceptual formula:

$$\text{Generation costs CSP+TES} \oplus \text{Required grid infrastructure cost} < \text{Generation costs of alternative technologies} \oplus \text{Cost of electricity storage}$$

The key question is: will the expected reduction in the generation costs of CSP + TES plants exceed the reduction in the cost of competing renewable energy technologies, taking into account the evolution of the electricity transmission costs and the costs of storing electricity at large scale? As it is well known, the combination of generation and heat storage has the attractiveness of dispatchability.[4] This feature

[2]Promotion of renewable electricity generation in the State of South Australia includes the indicated solar tower and, among other milestones, a 100-MW (129 MWh) battery. This is the largest in the world so far.

[3]It should be taken into account that the PV sector is a source of spectacular news. For example, [1] explain that some improvements in metal halide perovskites cells have increased their performance to 21.5%. This could lead to a cost of the kWh in a utility-scale PV plant of €cents ~1.5.

[4]The cost of hybridization should be added. However, it has been ignored for reasons of simplicity and because it seems plausible to assume the existence of CSP plants in the future with only solar operation all hours of the year.

of CSP, plus the reduction in the generation costs, competes with (onshore and offshore) wind and PV (large-scale plants) generation costs, plus the addition of the storage cost (which is also expected to decline). All in all, the Achilles heel of CSP generation may be the long distance that exists between most of the best electricity generation locations (in terms of solar resource) and the consumption areas, which leads to a requirement to invest in long and costly transmission lines. Although all renewable sources use local resources (solar irradiation, biomass, wind, etc.), the challenge for CSP generation is that, in general, the better locations in terms of DNI are not those where the population is concentrated, with the exception of a few countries whose cities are mostly located in the desert, such as those in the Arabian Peninsula. In most cases, however, the places with the best generation conditions are hundreds or thousands of kilometers away from consumption centers, as it is the case in Australia, Chile, China, Mexico, or USA. This represents a much greater handicap if transmission grids have to cross international borders and gets even worse if there are important geographical barriers in the middle, as in Western and Central Europe since the Mediterranean Sea is located between the Sahara desert and the consumption centers. Although the impact of transmission cost on the competitiveness of CSP generation is a complex issue (since it all depends on how that cost is shared between generators and consumers), the need to build long transmission lines does not favor the prospects for CSP. This is clearly a disadvantage which, as it is also the case with wind offshore, hardens the competitiveness condition, which requires sharp reductions in the electricity generation costs.[5] However, this requirement is partly mitigated by the advantage provided by its dispatchability.

Although the magnitude of the future deployment of CSP globally remains uncertain due to the aforementioned factors, it is expected that CSP will be most deployed in those geographical regions with ideal conditions, that is, high value of direct normal irradiation, accessibility to water resources, flat terrain, and proximity to natural gas pipelines and the electricity transmission grid. In these places, it can also provide a relevant service: to cover the needs for desalinated water and electricity for urban, agricultural, and industrial uses. It is in these regions where CSP generation will better resist the pressure of competing technologies and, particularly, PV.

References

1. Abdi-Jalebi M et al (2018) Maximizing and stabilizing luminiscense from halide perovskites with potassium passivation. Nature 555(7697):497–501
2. Bensebaa F (2011) Solar based large scale power plants: what is the best option. Progr Photovolt: Res Appl 19:240–246
3. Curry C (2017) Lithium-ion Battery Costs and Market. Squeezed margins seek technology improvements and new business models. BNEF Reports, Bloomberg New Energy Finance July

[5]Maybe increased transmission cost could partially by offset by larger scope projects (which take advantage of economies of scale) far away from any urban and/or industrial area, that is, where there are no problems of space availability.

5, 2017. Available at https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf. Accessed Jan 2018
4. Edenhofer O et al (eds) (2012) Renewable energy sources and climate change mitigation. Special report of the intergovernmental panel on climate change. Cambridge, Cambridge University Press
5. Enkhardt S (2018) Germany's auction for large-scale solar: Bids below €0.04/kWh for the first time. February 20, 2018. Available at http://www.pv-magazine.com. Accessed Mar 2018
6. GEA (2012) Global energy assessment. Toward a sustainable future. Cambridge and Laxenburg, Cambridge University Press and IIASA
7. Hill JS (2018) South Australia approves world's largest single-tower thermal solar plant. Clean Technica News. 12 Jan 2018. Available at https://cleantechnica.com. Accessed Feb 2018
8. IEA (2014) Technology roadmap solar thermal electricity. International Energy Agency (IEA), Paris. Available at https://doi.org/10.1007/SpringerReference_7300. Accessed Dec 2018
9. IRENA (2018) Renewable power generation costs in 2017. International Renewable Energy Agency, Abu Dhabi. Available at http://www.irena.org/publications. Accessed Apr 2018
10. Madlener R, Mathar T (2010) Development trends and economics of innovative: solar power generation technologies: a comparative analysis. FCN working paper No. 1/2009. Institute for future energy consumer needs and behavior (FCN), FBE/E.ON ERC, Aachen University. Available at http://www.eonerc.rwth-aachen.de/fcn. Accessed Sep 2013
11. Mir-Artigues P, del Río P (2016) The economics and policy of solar photovoltaics generation. Springer, Switzerland
12. REN21 (2018) REN21: renewables 2018 global status report. Available at: http://www.ren21.net/status-of-renewables/global-status-report/. Accessed Jan 2019
13. Wang J et al (2017) Status and future strategies for concentrating solar power in China. Energy Sci Eng 5:100–109
14. World Energy Council (2016) World energy resources. Available at http://www.worldenergy.org/wp. Accessed Jan 2019