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Policies to keep and expand the option of concentrating solar power for dispatchable renewable electricity

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ABSTRACT

Concentrating solar power (CSP) is one of the few renewable electricity technologies that can offer dispatchable electricity at large scale. Thus, it may play an important role in the future, especially to balance fluctuating sources in increasingly renewables-based power systems. Today, its costs are higher than those of PV and wind power and, as most countries do not support CSP, deployment is slow. Unless the expansion gains pace and costs decrease, the industry may stagnate or collapse, and an important technology for climate change mitigation has been lost. Keeping CSP as a maturing technology for dispatchable renewable power thus requires measures to improve its short-term economic attractiveness and to continue reducing costs in the longer term. We suggest a set of three policy instruments – feed-in tariffs or auctions reflecting the value of dispatchable CSP, and not merely its cost; risk coverage support for innovative designs; and demonstration projects – to be deployed, in regions where CSP has a potentially large role to play. This could provide the CSP industry with a balance of attractive profits and competitive pressure, the incentive to expand CSP while also reducing its costs, making it ready for broad-scale deployment when it is needed.

1. On costs and dispatchability

To curtail climate change to less than 2 °C global average warming, it is essential to eliminate CO_2 from the electricity sector by mid-century (Intergovernmental Panel on Climate Change (IPCC), 2014). This requirement for rapid change means that the carrying pillars of the electricity transition must be technologies already available for widespread deployment. Few, if any, disagree that renewables – and in particular wind and solar power – must and will shoulder most of the future power generation burden (Global Energy Assessment, 2012; IPCC, 2011; Obama, 2017). Since both solar photovoltaic (PV) and wind power are intermittent sources, finding ways to store large amounts of electricity has emerged as a crucial challenge for power sector decarbonization. Both wind power and PV would need to rely on a separate storage system, such as batteries, to become dispatchable. Concentrating solar power (CSP), in contrast, offers the possibility of integrated thermal storage and is able to store energy collected during day and use it for generation at a later time, including after sundown (Trieb et al., 2013). As thermal storage allows a CSP station to operate at a higher capacity factor, adding storage increases dispatchability but adds little or nothing to the levelised costs of electricity (LCOE) compared to a plant with no storage (Lilliestam et al., 2012; Mehos et al., 2016). This makes CSP a valuable option for producing dispatchable renewable electricity, both for bulk power and especially for balancing intermittent renewable sources.

Yet, CSP appears to be fighting a losing battle and there is a risk that the technology will not step out of its current small niche, as policy-makers focus their attention on support for the seemingly lower-cost

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wind power and solar PV. Despite having experienced strong cost reductions through technological improvements and economies of scale over the last 5 years – 2/3 lower than the support paid for the Spanish CSP fleet up to 2013 – recent (end 2016) CSP power purchase agreements (PPAs) are on average around \$0.15 per kWh,[1] see Fig. 1 (Lilliestam et al., 2017; Mehos et al., 2016). Although costs have decreased strongly, CSP remuneration is a multiple of recent PPAs from auctions for solar PV, which averaged \$0.05 per kWh in 2016 (International Renewable Energy Agency (IRENA), 2017).

However, it is important to note that whereas PV has run through much of its learning curve, CSP is still an immature technology with large cost reduction potential left: in 2016, the current global PV capacity was 300 GW, compared to 5 GW for CSP. When the world-record low bid for PV was \$0.12 per kWh, in late 2011, the global PV capacity was 75 GW – 15 times higher than the current CSP capacity (National Renewable Energy Laboratory (NREL), 2017; SolarPowerEurope, 2016, 2017).

Further, the comparison of LCOEs is misleading as it does not consider the dispatchable nature of CSP (when equipped with thermal storage (Jorgenson et al., 2014)). In 2015, Abengoa won a tender in Chile for a 210 MW hybrid PV/CSP plant; whereas the strike price (\$0.11 per kWh) was remarkable only for being the second *highest* of all bids, this was the first time a solar power station won a technology-open auction for 24/7 dispatchable electricity (HeliosCSP, 2015). In late 2016, SolarReserve bid for a PPA at \$0.06 per kWh for the Copiapó 240 MW solar tower with 14 h of storage, enough for continuous baseload generation, also in the Chilean Atacama desert (CSP Today, 2016). Whereas this is still more expensive than PV built on similarly optimal sites, CSP is far cheaper than PV combined with sufficient battery storage to achieve a comparable level of dispatchability: the cost comparison is especially beneficial for CSP for longer storage times (six hours or longer), and indeed large-storage stations are slowly becoming the norm for CSP stations across the world (Feldman et al., 2016; Jorgenson et al., 2014; Lilliestam et al., 2017). In sum, CSP with thermal storage is today cheaper than PV with batteries for the same level of dispatchability, and it is increasingly competitive – sometimes even with fossil fuels – in places where this dispatchability is rewarded.

Future price developments will dictate whether CSP maintains this advantage. On the one hand, both PV and battery costs are declining, and it is conceivable that a combination of the two could become less expensive than today's CSP with thermal storage within a few years. Feldman et al. (2016) suggest that PV with up to 6 h of battery storage is likely to close the cost gap to CSP in the next decade, whereas CSP remains competitive for larger storage installations. On the other hand, learning rates for CSP are similarly high as for PV and batteries (Lilliestam et al., 2017; Schmidt et al., 2017), and if CSP maintains a relative growth rate similar to PV and batteries, then it is likely to experience cost reductions that keep pace and perform better than in Feldman's analysis, maintaining its competitive advantage.

For this to occur, however, deployment of CSP with thermal storage will need to continue and increase, and herein lies a problem. In the long run, dispatchable renewables such as CSP may have an important role to play in all parts of the world, possibly including imports from deserts to non-desert regions (Labordena et al., 2017; Lilliestam et al., 2016; Lilliestam and Patt, 2015; Trieb et al., 2015; Veum et al., 2015). In most desert regions where CSP is a potentially competitive option in the short term, however, such as in the Middle East and North Africa, or parts of Latin America, PV and renewable power in general remain underdeveloped, and that in turn means that the dispatchability of CSP does not currently carry a high economic benefit. Today, most desert countries either have little intermittent generation, or they have

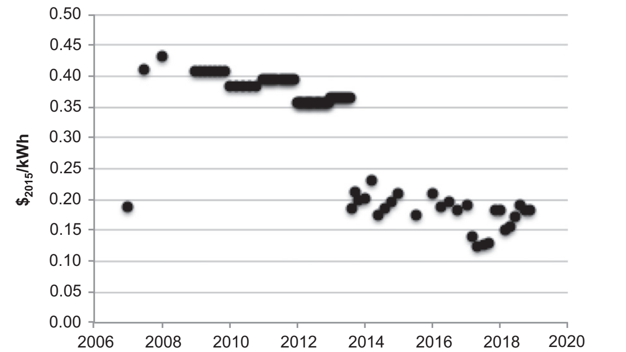

Fig. 1. Remuneration of all existing (end 2016) CSP stations and for projects under construction with disclosed data (about 80% of all projects). *Source*: www.csp.guru.

sufficient flexible fossil generation capacity to balance the PV and wind power they have; as long as climate policy is no strong constraint to these countries, this situation may remain. In other words, CSP right now is competing on LCOE against non-dispatchable renewables, and especially against PV without batteries. That is a competition that it loses, and there is reason to expect that investment in CSP could grind to a halt, or fail to start at all, in these regions unless governments maintain or introduce dedicated CSP policy support. Under such a scenario, by the time the renewable dispatchability of CSP does take on value and becomes truly needed, either alone or as a complement to balance PV and wind power generation, CSP will have been locked out of the market, and the world will have lost one of its weapons in the arsenal against climate change.

2. Risks and requirements for continued learning in CSP

In order to keep CSP as a valuable technology for decarbonization and, especially, for balancing of intermittent renewables, it is essential to develop it in a manner that leads to cost reductions, thereby maintaining and improving its attractiveness in the market. Achieving this is not simply a matter of adding new capacity, but requires more precise considerations in the design of support policies. In particular, such policies must address two critical risks that the CSP industry is currently facing.

The first risk is that one or more of the larger firms that manufacture CSP components or put them together into complete plants leave the market. This is a concern because several players have already left the market, leaving the current CSP market very thin, with only a handful of experienced firms active in each stage of the value chain, as shown in Fig. 2 (Lilliestam et al., 2017).

These firms have a lot of tacit knowledge, both with component manufacturing and plant construction but also with respect to the operation of a CSP plant. Unlike PV, or even wind, a CSP plant may require years of operation, with engineers making fine adjustments to its various components and the plant operation schedule, before it reaches full output (Desmond, 2016; EIA, 2017). The knowledge of how to do this is not tied up in patents, but in the living memories of engineers. If these engineers leave the industry, because their firm shrinks or exits the CSP market, then such knowledge and know-how is lost, and the cost curve for the technology as a whole suffers. This has already happened once in the history of CSP: although costs decreased strongly following the construction of the first CSP plants in California in the 1980s, the industry collapsed in 1991 and when expansion began again in Spain, 17 years later, the LCOE of the first Spanish stations was almost twice as high – and the learning curve had to begin anew (Lilliestam et al., 2017). Hence, continuity in the industry is essential: support policies for CSP must be designed so as to make it sufficiently profitable, with a sufficiently large and predictable stream of projects for firms to stay solvent, stay in the market and accumulate knowledge

[1] In fall 2017, two CSP PPAs (in Australia and Dubai) closed at below USD 0.07 per kWh (CSPplaza, 2017; Hill, 2017). Little detail of these deals is known, and at the time of writing, in October 2017, project construction has not started.