On the limits to solar thermal power: a reply to Trainer

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Abstract

In a recent article, Trainer argues that electricity from concentrating solar power (CSP) in winter would be unreliable and prohibitively expensive, even if generated in premium desert sites. However, he does not carry out a detailed analysis of the reliability or the cost, but bases his conclusion on five arguments, each of which is either irrelevant or erroneous. In particular, his research question, concerning the cost of a CSP kilowatt-hour during winter is irrelevant, and the answer misleading, because the power station will deliver electricity in summer too. A more relevant and not misleading question would be about the performance – the yearly levelised costs of electricity and the reliability – of a CSP fleet. We argue based on a detailed analysis of the performance of CSP in four deserts worldwide, that a coordinated fleet of CSP stations can indeed provide fully dispatchable electricity, and in some cases even baseload, at low cost.

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1 Introduction

In a recent article, Trainer (2014) examines the *limits to solar thermal electricity*. He concludes that concentrating solar power (CSP) will not be able to make a large contribution to meeting power demand, even in highly favourable sites, because the solar radiation is too low – and costs too high – in winter. Second, he sees the ability to store heat – otherwise seen as a main benefit of CSP – as unable to bridge extended periods of cloudy weather. Providing large amounts of reliable CSP in winter would require a massive overscaling of CSP stations and enormous storage capacities. This, and associated transmission losses and embodied energy of CSP stations, Trainer argues, lead to prohibitively high costs.

However, his analysis suffers from serious problems. We focus only on the aspects of his argumentation used for the cost calculations in Trainer's section 2.3.2.2, as a number of conceptual flaws distort his results and lead to misleading conclusions.

2 Five conceptual flaws

Trainer assesses the cost of 1 kW of CSP delivered "at distance" during winter, by dividing the investment cost of 6580 $/kW by 0.28 (the average CSP plant load during winter), and by multiplying the cost by 1.15 (accounting for transmission losses), 1.4 (accounting for large storage), 1.1 (accounting for embodied energy), and 1.3 (accounting for higher construction costs in remote areas), arriving at 55,000 $/kW. This cost is indeed remarkably and prohibitively high. However, Trainer's calculations are either irrelevant or wrong, for five reasons related to each calculation step.

1. Trainer's lead question of what CSP would cost in winter is irrelevant. The more relevant question, given that the CSP plant will generation electricity during summer as well, concerns the levelised cost of electricity (LCOE), averaged over the plant lifetime.
2. Trainer's statements about the reliability of a CSP *station* with little storage in winter are largely correct, but the lowest generation of a single station is irrelevant, as no demand curve can be met by a single power plant. Instead, the ability of a power plant *fleet* with significant storage to meet a particular demand curve (i.e. the fleet reliability) is more relevant, in particular combined with the costs of achieving high reliability.
3. Although larger storage capacities lead to higher investment costs per kW, this is again an irrelevant measure, as storage increases the capacity factor as well. Typically, adding storage hardly affects the

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LCOE but greatly enhances reliability (AETA, 2013; Lilliestam *et al.*, 2012).

4. Trainer's adding of embodied energy to the investment costs leads to double counting: the economic cost of the embodied energy is already included in the investment costs.
5. Adding 30% cost to account for "increased cost of construction in remote areas" also leads to double counting: the construction costs are already included in the investment costs. Further, Lovegrove *et al.* (2012:22), the only source Trainer provides for this, states 10-20% cost penalty.

3 The reliability and levelised generation costs of a CSP fleet

In an article published earlier this year, we analysed the capability of a CSP fleet to provide reliable electricity, following the demand curves of Europe (winter peak demand), California (summer peak) and a flat baseload demand curve, in the deserts of the Mediterranean region, South Africa, the United States and India (Pfenninger *et al.*, 2014). Our findings strongly contradict the results of Trainer, while being based on a more thorough analysis.

We show that the reliability of a fully uncoordinated CSP fleet is very high in summer, but indeed much lower in winter, despite the thermal storage. The LCOE is, however, far from prohibitive, at just below 15 ¢/kWh. Our model includes thermal inertia effects and losses, such as start-up and ramping behaviour. Future learning effects are likely to greatly reduce this cost, but we cannot know how much: here, we only use 2010 costs.

Reliability can be greatly increased at no or only moderate cost-penalty compared to the uncoordinated case if the fleet generation is coordinated, allowing one station to delay its production to compensate for expected downtimes of another. This way, a CSP fleet in the Mediterranean can always meet at least 50% of peak demand without cost penalty, see Figure 1. Following 100% of the European winter-peak demand curve – the worst case for CSP – causes less than 50% cost penalty, whereas following the summer-peak demand curve is only 20%, or 3 ¢/kWh, more expensive than unrestricted LCOE.

Very high reliability can be achieved at even lower cost penalty if both operation and design (solar field, power block, storage size) of the CSP fleet are optimised. For the Mediterranean CSP fleet, meeting 80% of the winter-peak and over 90% of the summer-peak demand curves comes at practically

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no cost penalty, whereas 100% winter-peak load-following comes at about 25% (+4 ¢/kWh) higher costs[1].

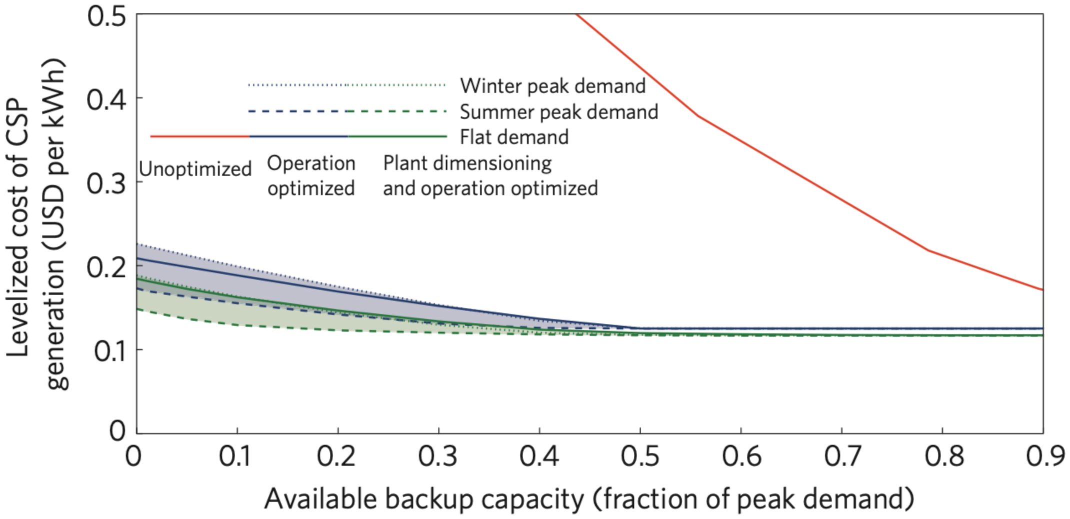

Figure 1: Costs of meeting various fractions of the three demand curves. An available backup capacity of 0.2 means that CSP would be able to cover 80% of the demand curve, whereas 0.8 available backup requires CSP to meet 20% of demand. Source: Pfenninger *et al.*, 2014.

The conclusion that very high reliability is possible at low cost holds for the Mediterranean and South Africa. As the deserts of India and the United States are smaller and have seasonally correlated cloud cover (monsoons), it is possible but expensive to provide up to 100% load-following there. For these regions, striving for full dispatchability throughout the year probably makes little sense. Even so, a CSP fleet is able to achieve high reliability at reasonable cost in all examined deserts.

Trainer ends his cost discussion by stating that "Although the derivation of this high [cost] figure cannot be based on confident assumptions at this stage it does indicate the factors to be clarified before concluding that solar thermal power could contribute significantly in winter at an affordable cost.” This is precisely what we have clarified: we showed that a fleet of dispersed CSP stations can be made fully dispatchable in summer as in winter and in some deserts is even fully baseload-capable at low cost.

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[1] For comparison: in the fully optimised Mediterranean case, a CSP fleet satisfying 50% the winter peak demand curve of Europe has average investment costs of just below 7000 $ (i.e. roughly the same as Trainer’s investment costs, before his cost-additions), whereas the 100% load-following case costs on average 9930 $/kW. Even this worst case is more than 5 times less expensive than the costs Trainer arrives at.

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