Costs of reducing water use of concentrating solar power to sustainable levels: Scenarios for North Africa

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Introduction

Concentrating solar power (CSP) has the potential to become a leading sustainable energy technology for the European electricity system. In order to reach a substantial share in the energy mix, European investment in CSP appears most profitable in North Africa, where solar potential is significantly higher than in southern Europe. As well as sufficient solar irradiance, however, the majority of today's CSP plants also require a considerable amount of water, primarily for cooling purposes. Already today North Africa is considered as a highly water stressed region, and experts even expect an aggravation of this situation in future due to climate change and population growth [1-4]. Considering these challenges, the objective of this study is to determine at what cost it is possible to reduce the water demand of CSP to sustainable levels when aiming at a large-scale deployment of this technology.

Methods

We examined the water usage associated with different CSP technologies and cooling systems in North Africa, and the cost penalties associated with technologies that could reduce those needs. We inspected four representative sites to compare the ecological and economical drawbacks from conventional and alternative cooling systems, depending on the local environment, and including an outlook with climate change to the mid-century. We then scaled our results up to a regional level to invenstigate how large-scale CSP deployment would affect the regional water resources. For this purpose we extended IIASA's MARGE model [5] to include the cost penalties of different cooling technologies (wet, dry and hybrid) and compared these costs with the cost for electricity generated from coal and gas.

Results

CSP has the potential to become an important source for the future energy mix of Europe and North Africa. On a regional level the use of wet cooling technologies would likely be unsustainable as it requires large amounts of water, especially in hot regions like the central Sahara, on average about 2,240 to 3,180 m^3/GWh. Applying hybrid or dry cooling systems reduces this demand significantly (Fig. 1). Though, it leads to considerable output losses, compared to wet cooling up to 6% (hybrid) to 9% (dry cooling) annual efficiency loss at our hottest site in Aswan, Egypt.

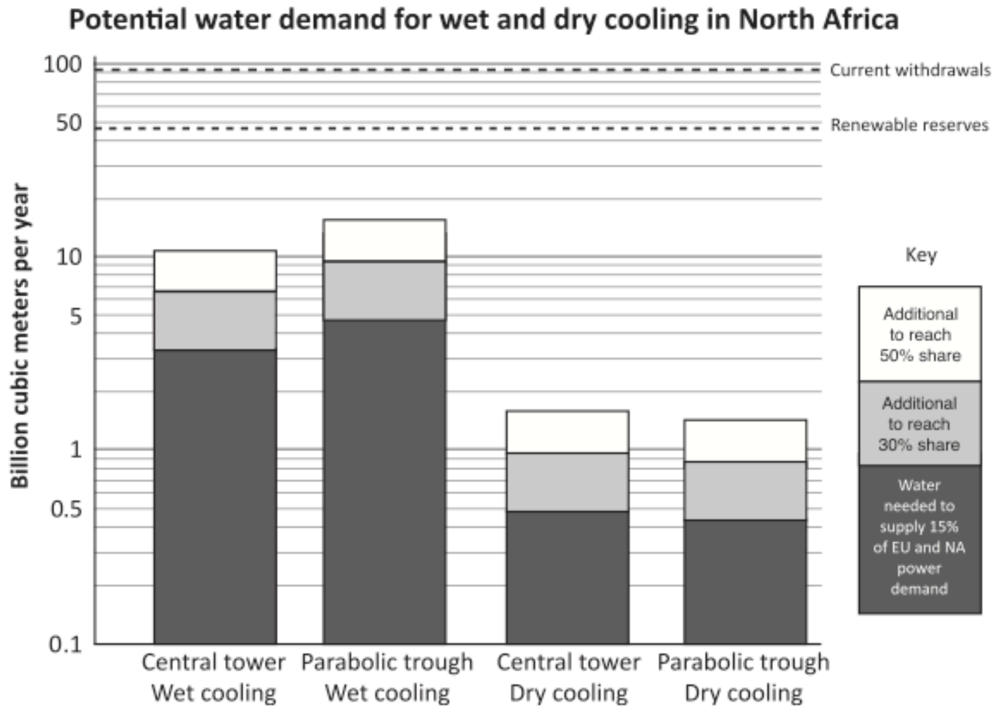

Fig. 1: Water demand of wet-cooled CSP (compare scenario from the German Aerospace Centre (DLR) for 15% CSP share from MENA [6]).

Dry cooling systems, as well as sourcing of alternative water supplies, would allow for sustainable operation. Their cost penalty would remain minor compared to the variance in CSP costs due to different average solar irradiance values (Fig. 2). Despite uncertainty, our study further shows that climate change in North Africa would increase the cooling demand additionally, while efficiencies would drop further. In an A1B scenario this means an increase in the cooling water demand of 2% for wet-cooled systems by 2050, for hybrid systems between 1.5% and 3%, depending on technology. The effect on levelized electricity costs (LEC) would still be marginal.

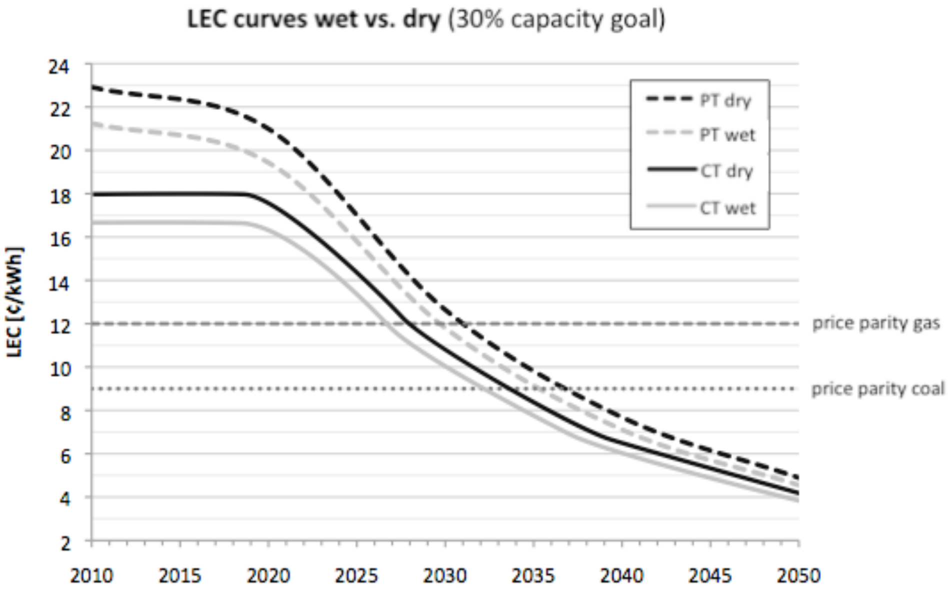

Fig. 2: LEC trend for wet and dry cooled CSP in the 30% capacity scenario, including transmission costs.

Thus, the sustainability of CSP does not depend on technical limitations or major economic penalties. Instead, it will likely depend on political regulation and governance to ensure an ecologically sound development that matches the appropriate technologies with different locations' precise needs.

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