Independent Review of
Morocco: Noor 2&3 Concentrated Solar Power Project

1. Introduction

This document comments on the eligibility of the project for CTF co-financing based on a review of project documents, which were made available to the reviewer.

2. Project scope and objectives

The Moroccan Solar Energy Agency (MASEN) was established by Law 13/09 to develop and manage the 2,000 MW of solar power facilities envisioned under the National Plan Against Climate Change and the Moroccan Solar Plan (MSP). MASEN made the strategic decision to focus a large part of its 2,000 MW program on development of solar plants using CSP technology with thermal storage.

The Project will support MASEN's implementation of the second, 350 MW phase of the Noor Solar Complex. This second phase consists of 2 distinct plants: (a) a 200 MW parabolic trough CSP plant (Noor II) and (b) a 150 tower CSP plant (Noor III). Both plants would be constructed on lots adjacent to Noor I that have already been acquired by MASEN. The Project is presented to the AfDB and the WB respective Boards for approval in advance of the conclusion of the procurement process to select private-sector sponsors to implement Noor II and III. As was the case with the Noor I the AfDB and the WB Project, this is important to provide bidders with sufficient comfort that the full financing for the project had been committed and, in particular, that the critically-important financing from CTF was secured.

3. Overall compliance with CTF objectives and criteria
Objectives

The CTF is designed to support high abatement opportunities and promote low carbon technologies including power sector projects that result in substantial reductions in carbon intensity of electricity production and increase substantially the share of renewable energy in the total electricity supply. This project fully satisfies these objectives.

Overall compliance with CTF criteria

3.1. Potential for GHG emissions savings

The project is expected to save 522 ktCO_2 per year directly, and to provide additional indirect climate mitigation benefit as it will help bring down the cost of CSP technology. The reviewer is not in position to precisely assess the veracity of this estimate, but the order of magnitude seems right. Direct CO_2 benefits might have been underestimated if the assumption that Noor 2 and 3 will mostly displaced electricity from efficient and relatively clean combine-cycle gas turbines using natural gas is proved partly wrong, and that the mix of electricity displaced comprehend a greater proportion of petroleum products burnt in open-cycle gas turbines, as is considered below. Whatever the exact number, this criterion for CTF financing is met.

3.2. Cost effectiveness

There are several issues relative to this criterion, which are considered in turn.

a) The project document states that "MASEN has issued the request for technical proposals in December 2013 in a 2-stage bidding process that is designed to award both projects as a package. This approach is expected to incentivize bidders, particularly those bidding for both projects, to optimize their technical design to ensure that MASEN receives the best possible price from both projects together."

However, very few companies in the world may have some practical experience of both parabolic trough and central receiver system technologies – in fact there seems to be only one such company. Therefore it is not sure that a single bid is more likely to generate interesting offers than two separate bids, which would have allowed more companies to take part for each plant and greater competition to take place. Furthermore, companies may be less able to deliver on the plant technology they do not know best.

b) The project document states that "Peak-hour generation yields higher value to MASEN and ONEE because it is expected to displace more expensive generation on the grid from combined-cycle gas turbines using imported liquefied natural gas."

However this statement may underestimate the economic benefits for Morocco of peak-hour generation, while at present the bulk of peak-hour generation comes from open-cycle gas turbines fuelled with imported petroleum products ("Fuel ONEE" and "Special fuel"), which are heavily subsidied by GoM through its "caisse de compensation" (for more than MAD 6.3 bn in 2011, according to the Conseil de la concurrence, Juin 2012), i.e. are not paid by ONEE for their actual price.

A shift towards imported liquefied natural gas may reduce the cost of peak-hour generation to some extent in the future, but the exact extent remains to be seen. At the margin, it is likely that OCGT will remain used for extreme peak, as this represents the least costly solution for plants that are only generating several hundreds of hours a year. More importantly, the substitution of oil products with natural gas rests on new contracts with Sonatrach, on new LNG port facilities, new interconnected gas network, and new gas storage facilities.

The document states that Noor 2 and 3 will displace more gas than Noor 1, which would essentially displace heavy fuel oil. This seems contradictory with the statement that Noor 2 and 3 will be more able than Noor 1 to displace marginal peak-hour generation. The slow change in the mix due to the fact that Noor 2 and 3 will be synced to the grid a couple of years after Noor 1 seems unlikely to be able to compensate for the limited ability of Noor 1 to shift enough electricity generation at peak hours, when precisely the marginal technology is oil-fired OCGT. Furthermore, it is difficult to ascertain that Noor 1 would ever suffice to displace oil in electricity generation, while oil represented 17% of annual electricity generation in Morocco in 2012.

c) The project document states that “MASEN made the minimum technical specifications of Noor II and III more flexible [than for Noor 1], specifying instead the minimum amount of peak hour generation needed from the plants [instead of a requirement of hours or storage, defined as hours of running at rated capacity from storage only]. MASEN left it to bidders to propose an optimized plant design to meet this peak hour requirement and offer the optimum size of thermal storage needed subject to utilizing a minimum of three hours of storage. In this way, MASEN anticipates that peak hour generation from Noor II and III would far exceed the amount now expected from Noor I, and, as a result, generate more revenues to MASEN from the sale of power on ONEE’s system. This approach leaves bidders flexibility to explore innovative approaches to meeting this requirement while minimizing the amount of thermal storage needed, which could also significantly impact the plants’ capital costs.”

This wording leaves unanswered a number of issues. What is the minimum amount of peak hour generation needed from the plants? How will it generate more revenues to MASEN from the sale of power on ONEE’s system – what is the structure of the rate? The precision “subject to utilising a minimum of three hours of storage” is somewhat surprising. Peak hours in Morocco, as defined for industrial customers by the ONEE, start essentially at sunset and last five hours all year round. A reasonable coverage of these peak hours is likely to require at least five hours of storage – and likely more to keep covering peak hours after one or two days with lower-than-average solar resource, especially in winter when the overall solar resource is only about 60% of the summer resource.

It would be preferable for actual plant design optimisation of the plants to give developers cost-reflecting power purchase agreement structured in function of time of delivery. One useful example is the third bid round of the Renewable Energy Independent Power Producer Procurement Programme of the Republic of South Africa, with its multiplier of 2.7 of the base price for electricity produced during peak hours. The price gap between marginal electricity generation costs during day time in Morocco, from coal today (and tomorrow from solar PV) and the generation cost during peak hours, from petroleum products burnt in open-cycle gas turbines (OCGT) today, is indeed close to this 2.7 multiplier – Morocco is very much like RSA from this perspective. In the future peak-hour generation may come from liquefied natural gas, might be slightly reduced but not much as discussed above.

Indeed, it would have been even better to let companies bid for the overall capacities in the number of plants and with the technology that better fits the identified needs, looking for the optimal combination of solar field size, possibly number of receivers (for towers), turbine capacities and storage size to respond cost-effectively to the generation of electricity during and beyond peak hours.

To summarise issues a) to c), although some economic benefits might be underestimated, the project may or may not offer the CSP response to the needs of the electric system of Morocco that would cost the least to the country. Thereby, it is difficult to appreciate if it will deliver the maximum possible benefits for the money the CTF will put in the project.

d) The cost-effectiveness criterion includes an analysis of the expected reduction in the cost of the technology at both global and local levels. However, the progress ratio for CSP considered in the Project document (80.5%) might be too optimistic. The IEA uses a more cautious 90%.

However, it may well be that progress ratio has to be considered independently for all sub-categories of the technology, as they are significantly different from each other. In this respect, the global cost reduction expected from Noor 3, which represents an addition of about 25% of the current global capacity of solar towers of 600 MW, and close to 100% of the global capacity of towers utilising molten salts as both heat transfer fluid and storage medium, would be significantly more important than those expected from Noor 2, which represents an addition of about 7% to the global capacity of parabolic trough plants.

Furthermore, cost reductions at country level, but also at regional level, may be more important than the global progress ratio suggests, as these projects are likely to have a significant influence on the soft costs of future projects, lowering the costs of capital in alleviating the technology and country risks, lowering the costs of development through the experience gained, etc.

In sum, the information made available to date does not allow to firmly conclude that the project is the most cost-effective CSP solution to the energy demand of Morocco, and hence, the most cost-effective expenditure for the CTF in this area. Hopefully the remainder of the process will provide answers to the questions raised, and/or allow for improvements in the design of the plants and the design of the multiple agreements between the developer, MASEN, the ONEE, and the Government of Morocco.

3.3. Demonstration potential at scale

At a global scale solar thermal electricity (STE) from CSP plants should represent 7% to 11% of global electricity generation by 2050 in both variants of the 2°C Scenario (2DS) of the most recent *Energy Technology Perspectives* (ETP) publication (2014).

This Project is by far the largest of its kind in North Africa and the Middle East, and on continental scale can only be compared to projects in South Africa. It thus has considerable transformation potential as Africa and Middle East could be the regions with the highest penetration of solar thermal electricity (STE) – the only two regions in the world where STE would be more massively generated than PV electricity in the 2DS of *ETP 2014*. This criterion for CTF financing is thus fully met.

3.4. Development impact

The Project will have many positive direct impacts for the development. It will strengthen the energy security of the country, reducing its dependence to energy imports (oil, gas, electricity), based on a local energy source. It will create local jobs, as a minimum 35% of the costs of the project is expected to be sourced locally. It will raise skills of local companies and staff, which may help them participate to the global deployment of CSP. It will offer environmental co-benefits in reducing the emissions of air pollutants from fuel combustion (SOx, NOx, Particulates, heavy metals, VOCs). These direct impacts will be multiplied with the replication of the project in Morocco and in the whole Middle East and North Africa region. Hence, this criterion for CTF financing is fully met.

3.5. Implementation potential

The Project is to be implemented by an Agency that has been created with this specific purpose, with the support of the highest political authority of the Kingdom, and in close co-operation with the ONEE. The potential for implementation thus appears very high

3.6. Additional costs and risk premium

Although benefits of the project might have been underestimated, and could also be increased through better design and implementation of the project, a cost gap would likely remain to be filled. CSP plants are very capital-intensive, as the "fuel" has to be paid at once when the plants are built. Up-front expenditures are thus disproportionately important by comparison with other thermal plants using combustible fuels, fossil or not. The cost of capital is thus of primary importance in the calculation of the levelised cost of electricity. This cost is high in developing countries due to the addition of risks – technology risks, political risks, exchange rate risks, etc. this fully justifies the financing of CTF to reduce costs of capital and thus reduce the cost gap of this project (although the correct comparison should not be made with the average electricity price of ONEE but rather with the total cost of electricity for the country, including all subsidies, and depending on time of delivery of electricity).

4. Technology readiness

The parabolic trough plant CSP technology is a commercially available technology with high mitigation potential. The solar tower CSP technology is a technically proven technology on the verge of becoming commercially available, and has an even greater mitigation potential. The above-mentioned *ETP 2014* publication of the IEA suggests that CSP technologies have a potential to reduce global energy-related CO2 emissions by about 9% (over the laissez-faire scenario) from now to 2050.

5. Conclusion and recommendations

In conclusion, the project fully meets all criteria for CTF funding but one, cost-effectiveness for which interrogations remain at this stage.

Annex I: Matrix of comments and team's responses

Initial comments	Team's responses	Final comments
MASEN has left the possibility for bidders to bid for both Noor II and III. However, very few companies in the world may have some practical experience of both parabolic trough and central receiver system technologies – in fact there seems to be only one such company.	It is important to note that the procurement underway is for the selection of sponsors that will develop, design, construct, own, and operate the plants. It is also important to note that bidders can bid for one of the plants or both. Three consortia were prequalified for Noor II and four for Noor III. The consortia are free to select the EPC and O&M contractors as well as equipment manufacturers able to satisfy the technical requirements of each plant. There is no requirement that the contractors be the same for both projects, leaving the sponsors the freedom to retain the most qualified contractors for the type of plant involved.	Answer's is fully satisfactory
The project document states that "Peak-hour generation yields higher value to MASEN and ONEE because it is expected to displace more expensive generation on the grid from combined-cycle gas turbines using imported liquefied natural gas." However this statement may underestimate the economic benefit for Morocco of peak-hour generation, while at present the bulk of peak-hour generation comes from open-cycle gas turbines fuelled with imported petroleum products (heavy fuel oil, diesel oil and "special" fuel), which are heavily subsidied by GoM	ONEE's estimates indicate that Noor I displaces much of the subsidized fuel oil generation in the system, leaving only a small amount that would be displaced by Noor II and III in the early years of their operations. The base case assumes that Noor II and III will mostly displace LNG-fired CCGT generation. This fuel is currently not subsidized by the GoM.	Noor I has a capacity of 160 MW, and 3 hour storage, meaning it can deliver at best 175 GWh of peak electricity after sunset displacing fuel oil generation. The generation of electricity from oil-fired plant has been of 5 756 GWh in 2012 and 4 630 GWh in 2013 (thanks to a better availability of hydropower), 26 times greater that peak generation from Noor I. Assuming that Noor 1 will displace "much of the subsidised fuel oil generation" requires very strong assumption relative to the development of natural gas use in the country in only a few years.

the document states that Noor 2 and 3 will displace more gas than Noor 1, which would essentially displace heavy fuel oil. This seems contradictory with the statement that Noor 2 and 3 will be more able than Noor 1 to displace marginal peak-hour generation. The slow change in the mix due to the fact that Noor 2 and 3 will be synced to the grid a couple of years after Noor 1 seems unlikely to be able to compensate for the poor ability of Noor 1 to shift enough electricity generation at peak hours, when precisely the marginal technology is OCGT.	See response above	
What is the minimum amount of peak hour generation needed from the plants? How will it generate more revenues to MASEN from the sale of power on ONEE's system. What does mean the precision "subject to utilising a minimum of three hours of storage"?	The RfP required, as part of the minimum functional specifications, that the plants would be able to provide a minimum number of peak hour generation. Unlike Noor I where MASEN specified the number of storage hours that the plant should be capable of, MASEN elected to specify instead the number of peak hours that the plants are expected to provide energy to leave bidders the flexibility to optimize the plants' design to minimize LCOE, but indicated that 3 hours would be the minimum level of thermal storage accepted. MASEN expected that, to meet the peak hours requirement, a level of storage above 3 hours would be needed.	The question relative to the minimum amount of peak hour generation remains unanswered. The exact meaning of the minimum of three hours of storage remains a mystery. The only precision made is about the rate structure – see comment below.
It would be preferable for actual plant design	MASEN provided peak hours, and off-peak hours	Off-peak tariff is thus 15% less than peak tariff. This

optimisation of the plants to give developers cost-reflecting power purchase agreement structured in function of time of delivery. One useful example is the third bid round of the Renewable Energy Independent Power Producer Procurement Programme of the Republic of South Africa, with its multiplier of 2.7 of the base price for electricity produced during peak hours.	and night hours pricing to aid bidders in designing their bid tariffs on the basis of the proposed design and number of hours in each time slot involved. Off- peak tariff is peak tariff multiplied by 0,85 . **"Night Hours Time-Slot"** shall designate the hours in a Day which are not included in the Peak Hours Time-Slot and in the Off-Peak Hours Time-Slot. Delivery of power during night hours, and eventual compensation is conditioned to ONE's approval.	percentage may reflect the cost gap for ONEE of generating electricity at peak time, mostly from oil and gas, from generating electricity off peak, mostly from coal. It surely does *not* reflect the cost gap for the country, which should be calculated with the heavy subsidies for the oil burnt in ONEE thermal plants. The rate of subsidisation was assessed in 2011 at 59% for the Fuel ONEE and 63.5% for the Fuel Special (conseil de la concurrence, Juin 2012).
it would have been even better to let companies bid for the overall capacities in the number of plants and with the technology that better fits the identified needs, looking for the optimal combination of solar field size, possibly number of receivers (for towers), turbine capacities and storage size to respond cost-effectively to the generation of electricity during and beyond peak hours.	The overall definition of Noor II and III is driven by the need to balance technical risk with the willingness to develop an innovative large solar tower with storage. In addition, from the procurement standpoint, some design constraints simplify the technical comparison of the offers, that could have become more subjective in case of an open design. Further, opening up the technologies may also make it quite difficult to develop Morocco's local manufacturing capacity that needs a minimum threshold of projects to develop. However, please note that even if MASEN requested the use of specific technologies for Noor II and Noor III, the MFSs provide enough flexibility for the bidders to	Once technically competent bidders have been pre-selected, and a cost-reflective rate implemented (with one or several coefficient linking a base price with various prices for various times of the day/season), the comparison of the offers could simply rest on the lowest offer. This would allow to keep open all technology options.

	select the capacity for each plant within a wide range and optimize their designs. The land made available for each plant is large enough to allow the bidders to select high solar multiples and high storage capacities, even at the maximum gross capacity allowed. Bidders are also allow to propose combined designs, keeping the capacity requirements established in the project, if that helps them to minimize levelized generation costs.	
Initial comments	**Team's responses**	**Final comments**

Paris, 27 May 2014,
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