RE Flagship Projects in the ECOWAS Region

Case Study

NAVRONGO SOLAR PV PROJECT

Ghana

BACKGROUND

The 2.5 MWp Navrongo solar PV project was the first utility-scale PV plant in Ghana, and one of the first of this size in the whole region. At project commissioning in 2013, Ghana was in a phase of fast economic growth and lagging power capacity additions, so that a lack of generation capacity seemed the primary sector planning concern. However, the recent slow-down together with aggressive capacity additions has changed this situation for now, and the Navrongo project matters mainly due to its demonstration effect and as a substitution for expensive thermal power generation. Today, the plant capacity corresponds to about 0.1% of Ghana's peak load and feeds about 3.8 GWh per year into Ghana's national power grid, which is operated by *Ghana Grid Company* (GRIDCO). The predominantly rural distribution company *Northern Electricity Distribution Company* (NEDCO), which serves Northern Ghana, is the power plant's off-taker. Situated less than 10 km from the country's Northern border with Burkina Faso, the project site is far away from the country's main load centers and large power plants.

[1] The first phase (1.9 MWp) was commissioned in February 2013.

KEY FACTS

Site	Navrongo, Upper East Region, Ghana
Technology	Grid-connected solar PV power plant
Generation capacity	2.5 MWp
Annual generation	3,843 MWh (2014)
Developer, owner and operator	Volta River Authority (VRA)
Off-taker	Northern Electricity Distribution Company (NEDCO)
Engineering, procurement and construction	China Wind Power (CWP)
Commissioning	June 2013[1]
Investment cost	USD 9 million
Financing	VRA on balance sheet

PROJECT **DEVELOPMENT**

The project has been developed and financed by *Volta River Authority* (VRA), Ghana's preeminent parastatal power generation company, which is also the owner and operator. VRA was founded in the 1960s and operates the giant Akosombo hydro plant, which allows for high values of PV and wind feed-in due to its storage reservoir and concomitant potential for peak shifting.

The project was meant to be the first of a whole series of VRA-owned RE investments under the company's *Renewable Energy Development Programme* (REDP) formulated in 2010.[2] The programme comprises at least 14.5 MWp PV at three to four sites in Ghana's North and about 150 MWp wind power close to VRA's Akosombo plant or directly at the coast. VRA has engaged *Lahmeyer International* (a German engineering company which is now part of *Tractebel* and the ENGIE group) as owner's engineer for the REDP in general and Navrongo in particular. Due to delays in procurement of the owner's engineer, VRA undertook the selection of suitable sites based on an evaluation of radiation conditions, infrastructure and network access as well as preliminary network load centre appraisal. Another consideration for selecting rather remote sites in Northern Ghana was that the land is more affordable than in the vicinity of the country's main load centres.

VRA also prepared the specifications and the relevant tender documents and completed the procurement process. *Lahmeyer International* then reviewed the evaluation report at the start of their assignment. VRA also hired a consulting firm to conduct an environmental study in March 2012, when the procurement process was already well advanced.

The project was approved as a Clean Development Mechanism (CDM) project under a multi-country Programme of Activities (POA) developed by the UK-based *Standard Bank* in late 2012.[3] It was one of the first CDM projects in Ghana, and due to unfortunate timing (the drop in Certified Emission Reduction (CER) prices in 2012, when carbon credits lost 90% of their value), the expected revenue from CER sales became so small that the POA was no longer pursued.

[2] The technologies covered by the REDP are PV, concentrated solar power, wind, hydropower and biomass. Financial closure for another 12 MWp solar PV at two sites in the Upper West region was achieved in 2017 and commissioning of both plants is now planned for 2018. The wind projects under the REDP are delayed, but significant steps such as wind measurements and environmental studies were completed.

[3] For more information on the »Standard Bank Renewable Energy Programme« please visit https://cdm.unfccc.int.

PROJECT MILESTONES

2010

Start of VRA's REDP and start of procurement of owner's engineer

2011

Tender of Navrongo EPC and O&M contract and engagement of Lahmeyer International as owner's engineer

2012

February: EPC and O&M contract awarded to China Wind Power (CWP)

March: Start of construction

September: Approval as CDM project by Designated National Authority

2013

February: Commissioning of phase 1 (1.9 MWp)

April: Start of commercial operation

August: End of O&M contract with CWP

PROCUREMENT AND CONSTRUCTION

The plant has been procured under a competitive tender that led to price offers that were in line with international benchmarks at the time. *Lahmeyer* and VRA's own engineers served as tender agents and owner's engineers. As can be seen in the overview of project milestones, the time spans from project start to tender, from tender start to contract award, and from contract award to plant commissioning have been remarkably short, even without considering the early pioneer role of the project. This is an achievement by itself.

However, the experience with the winning Engineering, Procurement and Construction (EPC) contractor *China Wind Power* (CWP) was mixed. CWP unilaterally decided to deliver an inverter concept that was different from the one presented in their technical offer: not the expected modular central inverters but rather normal central inverters. This is a significant downside, because the new inverter concept affected the envisaged O&M plans and leads to longer downtime in case of inverter problems. VRA did not insist on the initial inverter concept yet. As a direct result, VRA now has three cumulative problems, two of which have been observed in the field: (i) the annual yield and performance ratio (PR) are suboptimal; (ii) one of the inverters already failed; (iii) additionally, if there are future inverters failures, replacement will be difficult, with replacement times adding to PR losses. This leads to unnecessary yield losses. In addition, VRA faced the problem that the Instructions Manual and some of the staff provided by the EPC contractor during construction and the initial 6-month joint O&M phase was not intelligible to their staff due to language problems, which is posing some challenges up to now.

The system has been procured with an undue focus on (i) the lowest possible CAPEX instead of (ii) optimal lifetime cost and system yield — let alone (iii) optimal net system benefits. This is a general problem in many nascent PV markets: System quality and acceptance tests are neglected, which can lead to significant welfare losses. In this specific case, for example, the acceptance tests did not involve most of the recommended steps before and after the actual first feed-in, nor did the actually implemented basic PR test include proper documentation of details, equipment and methods which would be required to judge its error margins. More demanding tender specifications and a state-of-the-art series of commissioning tests would probably have allowed for a system with better lifetime cost-benefit ratio. However, it should be noted that this is a general problem of PV tenders under public procurement rules in emerging markets: The generally established »simple« tender documents often lead to unnecessary welfare losses from lower than necessary net present value (NPV) of total system costs (and thus true levelised cost of energy — LCOE) due to a lower than appropriate system quality. Public procurement processes typically focus on cost to avoid manipulation by way of subjective (and therefore possibly ambiguous) evaluation criteria. This was also the case in the Navrongo tender where simple pass-fail criteria were used for the technical portion of the evaluation and specificc installed cost and indicative energy cost were used for the commercial.

Most developers and donors, however, would rather use a score card approach for quality and cost based selection (QCBS) type procurement. Procurement with pass-fail criteria assumes that each single system component can be defined with a quantitative minimum quality level and therefore evaluated with a binary pass-fail approach, without giving consideration to relative component importance or system-interaction issues. Alas, this is not true for PV systems as well as single components because the performance of solar generators depends on the specific interplay between these separate system components. Therefore, the vast majority of private sector project developers — who optimize the outcome for PV investors — do not evaluate EPC proposals based on pass-fail criteria, but score the quantity of each component and the overall system based on their probable performance in terms of yield and cost-effectiveness. This »quality score« is then weighted with investment cost to reflect the simple fact that net present value is composed not only of today's investment, but also of future yield and O&M costs.

TECHNICAL ANALYSIS AND OPERATION

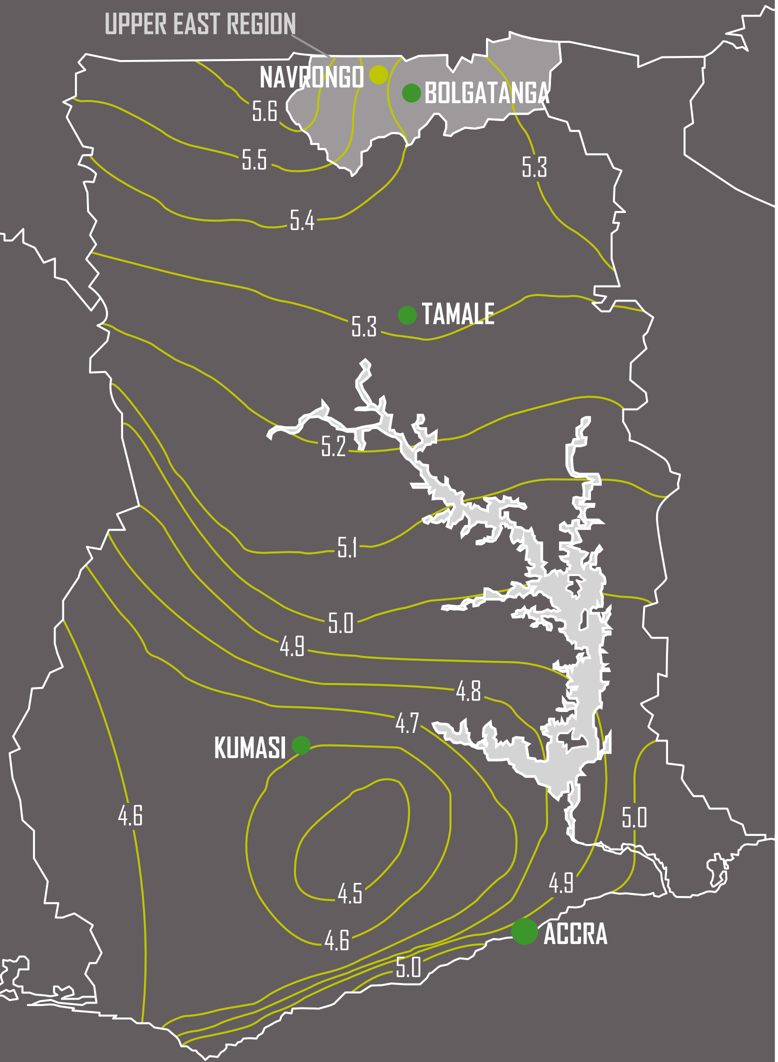
The Navrongo plant is operational and has been feeding into the grid since February 2012.[4] Current energy generated is about 3,800 MWh per year.[5] It is of reasonable quality in light of the plant's pioneer role. On the upside, modules, grid interconnection, control room and VRA on-site staff meet international standards and cabling, mounting and civil works are of solid quality. On the downside, a few smaller, practical issues that meet the eye of an experienced PV installer or operator could have been better solved without much effort: the module rows and plant surroundings lack a path with sufficient space for easy inspection and maintenance by car; the fence (while sturdy) does not prevent small animals from entering the perimeter, and the lignite used for ground coverage is prone to generating additional dust that can settle on the PV modules.

[4] The first phase (1.9 MWp) was commissioned in February 2012, and an additional 600 kWp was commissioned in June 2013.

[5] The generation was 3,843 MWh in 2014 (VRA 2015).

SOLAR RADIATION MAP OF GHANA

(kWh/m²/day)



ECONOMIC AND FINANCIAL ANALYSIS

The main economic benefit is the value of the thermal fuel that is saved thanks to PV injection (operational benefits). On top of that, there are other benefits (such as reduced energy price volatility, jobs, the present monetary value of the carbon saved, etc.) but they are smaller by an order of magnitude. However, they are not required to confirm that the project is economically sound, even at the relatively high 2013 CAPEX (compared to today's PV CAPEX — 3.6 USD/Wp in 2013 vs. 1.2 to 2 USD/Wp today[6]). As Navrongo was the first utility-scale PV plant in Ghana, and the electricity mix includes a significant share of fairly high-priced generators, the output of the solar power plant replaces high-cost fuel, and the resulting operational benefits (avoided thermal generation costs) are significant and easily exceed the project cost. Based on a recent study of operational benefits in Ghana (GIZ 2017), the energy injected by the Navrongo plant is worth between 0.15 and 0.35 USD/kWh (depending on the scenario for future fuel prices, carbon values and future generation and transmission additions). Assuming an average 0.20 USD/kWh for example, the total lifetime cost of slightly above EUR 9 million (including O&M) allows an annual return of about 760,000 USD/year. This example corresponds to positive net present values for the Navrongo investment for all interest rates below 7%. At today's lower PV CAPEX of around 2 USD/Wp (installed in Ghana), the initial investment would be closer to USD 5 million, so that it would make sense for investors with weighted average capital costs (WACC) up to 15%. Once PV CAPEX will have reached and passed today's international record benchmarks for low-cost installation (around 1 USD/Wp in Germany in late 2017), this hurdle rate will increase to even higher levels.

ENVIRONMENTAL BENEFITS

The project's main environmental benefit is the effect on global climate, via the thermal fuel that is replaced with the PV energy when injected. If the Akosombo or Bui hydropower plants were operated with a higher evening load (at constant daily injection), additional fuel (and thus carbon) savings would be possible, because energy injected at solar noon could be used to replace the evening peak generators. The CDM POA suggested annual carbon savings of 1,074 tons of CO_2 for the initially planned 1.9 MWp size, which translates into about 1,400 tons CO_2 per year for the actual 2.5 MWp plant. Recent studies of the actual carbon saved at optimal national dispatch confirm this estimate by and large.

[6] See for example IRENA (2016).

CONCLUSIONS

As the first utility-scale PV plant in the country — and the third in the ECOWAS region — this landmark project deserves praise for its demonstration and RE market development effects in Ghana and beyond. Surprisingly, this important »policy benefit« has not received due recognition to date, compared to similar RE pioneer projects in other countries. By project inception, very few grid-connected solar plants had been installed in the region and on national level. In Ghana, only a few smaller grid-connected demonstration systems had been installed before by technology research institutions and donors.

The sequels and prequels to Navrongo make this project the perfect example for the second step in a typical, well-sequenced, 3-step national PV scale-up path:

i. An initial »technology demonstration« phase in the narrow sense, with a few very small kWp installations that are close to research facilities (typically universities) and public attention (this is less necessary today than it was in the years leading up to Navrongo) is followed by
ii. one or more slightly larger 1 to 5 MWp-size PV power plants that are procured and operated by some of the main current sector players themselves, which allows ongoing learning about technology issues in the broader sense (including system integration) as well as financing and procurement (including specifications and sound tender documents for EPC contractors). These projects also serve to increase the awareness of PV as a mature technology option for modern utilities and power systems, which can actually create returns for investors (financial benefits) while saving significant fuel and money (economic benefit — on SPV and system level).
iii. Ideally, the latter would then lead to several follow-up projects of increasing sizes, so that public and private sector can learn, local players can compete in future tenders, and the impact of errors that always happen in the initial projects (see procurement recommendations below) would be limited — while subsequent, large-scale projects would not repeat those errors. Indeed, Ghana is currently at step iii, with one 20 MWp power plant built close to Accra in 2015 (by the Chinese firm BXC)[7] and several projects with capacities of 10 MWp and more in various stages of development by different players and in several regions of Ghana. These include the two projects with a combined capacity of 12 MWp that are currently being developed by VRA in the Upper West Region with financing from KfW. PV is better suited for such a sequenced scale-up than other RE technologies, due to its scalability.

In the scaling up of solar PV development Ghana it has to be taken into consideration that (i) small advantages in PV yields due to slightly higher irradiation in the North (Navrongo 5.5 kWh/m²/day compared to 5.1 kWh/m²/day in Accra)[8] need to be weighed against (ii) the higher logistics costs in remote areas (which raise CAPEX and OPEX), and more importantly (iii) the significant line losses that often occur on the way to far-away load centres: When such remote power plants feed in at supposedly low energy generation cost, transmission losses often lead to much lower benefits in terms of actual system fuel savings and thus higher unit costs for the useful energy unless they supply nearby load centers.

[7] BXC is a subsidiary of Beijing Fuxing Xiao-Cheng Electronic Technology Stock Com Ltd.

[8] Energy Commission: Solar Radiation in Ghana, http://energycom.gov.gh/documents?download=18:solar-data

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