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Mobilising Renewable Energy Investments

Uganda: Captive Power

Case Study: 300 kWp Rooftop Solar PV System at an Office Building

SITUATION DESCRIPTION

This project Case Study investigates the feasibility of a solar PV system investment at a typical larger office building in Kampala, Uganda. The office block is representative of a number of similar buildings in large urban areas that have sufficient roof space to install such a solar PV plant to help save on electricity costs.

The office building electricity is supplied by Umeme as a tariff code 20 (medium industrial) customer. The annual energy needs of the building are estimated to be 1,639,292 kWh, with a potential maximum demand of up to 250 kW. Approximately 73% of electricity consumption is during daytime.

This is because the PV inverters do not have black start ability nor can they form a grid. They need a grid frequency to which they can synchronize. This is only available if an operating grid is present or if the system is integrated with a diesel back-up generator. Alternatively, if the PV system charges a battery, its discharge could supply (some of) the building loads.

PV SYSTEM CONFIGURATION

The available rooftop space is about 2,660 m². This allows for a potential PV system size of up to 300 kWp. However, in this Case Study, the plant is sized at 150 kWp because not all the roof may be useable due to existing structures, weight limitations, shading and other considerations.

The solar PV system is modelled for self-consumption only (no surplus electricity production to feed into the grid) and without battery storage. The system is grid-tied and not integrated with any back-up diesel generation. This implies that during grid power outage, the solar PV system will stop supplying the building loads.

PLANT CHARACTERISTICS

The plant annual generation was determined using SolarGIS irradiation data and PVsyst software taking into account the plant size and solar irradiation in Kampala. A system lifetime of 25 years is assumed. The proposed solar PV plant has the following characteristics (**Table 1**).

The impact of system degradation, system losses, temperature, grid outages, cloud cover and panel soiling have been considered to arrive at the energy yield. Shading from neighbouring buildings is expected to have an impact in the morning hours.

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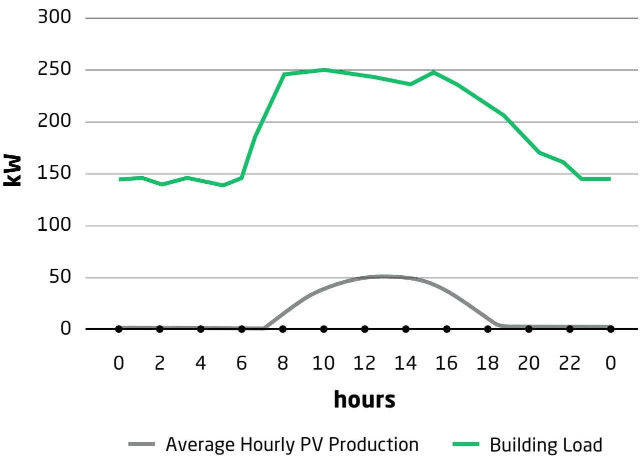
TABLE 1. Solar PV system characteristics

PARAMETER	UNIT	VALUE
Irradiation at 10° tilt	kWh/m²/y	1,928
Approximate yield	kWh/kW/y	1,458
System size	kWp	150
Annual grid outage time	%	1.6
Annual generation year 1	kWh	215,201
Annual degradation	%	0.5
Development & construction time	months	6
Lifetime	years	25

The average PV output (kW) over 24 hours is shown in comparison to the building load. Maximum solar output on the sunniest day is in the range of 140 to 150 kW.

The PV production will in reality fluctuate over the year based on solar irradiation levels. The highest system output is expected in December–March and September and the lowest in May–August.

FIGURE 1. PV production vs. building load (24 hours)



CAPITAL AND OPERATING COSTS

Capital expenditure (CAPEX) includes the typical solar PV equipment and associated costs. Apart from modules and inverters, the "balance of plant" costs are for mounting racks, cables, collection boxes, etc. All other costs, such as for transport (e.g. from Europe to Uganda via Mombasa, Kenya), import, design and commissioning, are covered under miscellaneous costs. Because the system is roof-mounted, no civil works are foreseen. A development and construction period of six months is assumed, which includes the time needed for permitting processes and equipment import.

For the annual operating costs (OPEX), a percentage of the CAPEX is applied that represents a suitable estimation. These costs include cleaning the panels (at least twice a year), occasional visits of technicians, replacement of spare parts as well as insurance costs. The building management is assumed to take care of minor maintenance measures.

The estimated costs are based on project experience in Uganda and East Africa in 2017. A UGX-EUR exchange rate of 0.000235 is used.

The case study is based on an investment in EUR. The analysis is performed before any consideration of financing[1]. The effects of currency exchange rate fluctuations or hedging costs are also not considered. Furthermore, no generation license is required for a self-consumption captive power plant of this size and an Environmental Impact Assessment and certificate of approval is unlikely to be needed.

TABLE 2. CAPEX and annual OPEX

COMPONENT	UNIT COST	PROJECT COST	
	EUR/kWp	EUR	UGX
Modules	450	67,500	287,516,250
Inverters	150	22,500	95,838,750
Balance of plant	500	75,000	319,462,500
Miscellaneous	300	45,000	191,677,500
Total PV	**1,400**	**210,000**	**894,495,000**
O&M costs/year	1.5%	3,150	13,417,425

1) It should be noted that as of the end of 2017, all of the seven existing solar PV captive systems in Uganda had been implemented without financing; the owners made the entire investment and/or grants were used. However, the accompanying Model Business Cases investigate different financing scenarios. The Model Business Cases are accessible www.get-invest.eu

LEVELISED COST OF ELECTRICITY FOR THE SOLAR PV SYSTEM

The levelised cost of electricity (LCOE)[2] is calculated using a discount rate of 8% and determining PV system costs and electricity production for each year separately using the discount factor. The discount rate is based on an assumption that the project owner could access debt in a hard currency at an interest rate of 7%[3]. In Uganda, the Sustainable Use of Natural Resources and Energy Finance (SUNREF) initiative developed by Agence Française de Développement (AFD) could be a notable option for such projects. Alternative discount rates are also shown for comparison.

The base year of the calculations is 2017. Twenty-five and a half years are considered in the analysis (6 months development and construction, 25 years operation). The division of the present value of costs by the present value of electricity production results in an LCOE as presented for different discount rates.

TABLE 3. Levelised cost

ITEM	EUR/kWh	UGX
LCOE at 8% discount rate	0.114	487.59
LCOE at 10% discount rate	0.130	555.26
LCOE at 12% discount rate	0.147	626.54
LCOE at 14% discount rate	0.164	700.66

COMPARISON TO ACTUAL ELECTRICITY COSTS

The electricity production costs of the solar PV plant are compared to grid electricity bills for the office building without considering the monthly fixed service fee (EUR 5.26, UGX 22,400) charged by the utility, as this charge cannot be avoided.

Also, due to fluctuations in the output of the 150 kW PV system it may not be possible to consistently offset any of the estimated 250 kW maximum demand of the building that is met by grid power, therefore, the captive plant may not be able to reduce the monthly maximum demand charge (EUR 3.91 or UGX 16,644 per kVA per month).

In order to determine which time-of-use electricity tariff the PV production would offset, a simulation of the solar irradiation potential was conducted. It was found that the solar PV electricity is generated almost entirely during the shoulder tariff hours (06:00–18:00) of Umeme. Only a limited percentage of PV production (0.37%) falls in the peak tariff hours (18:00–00:00) and none during off-peak (00:00–06:00).

The energy charges per kWh for code 20 (medium industrial) customers for the three time-of-use periods are presented for the 4th quarter of 2017.

To assess the cost of electricity that the PV system would offset in the future, the Umeme energy charges were adjusted for annual inflation. For 2018 and 2019 a rate of 5% was applied and a rate of 4% for the following years, based on recent trends and electricity sector forecasts[4]. The same inflation rates were also applied to the PV plant operating costs.

TABLE 4. Umeme tariff code 20 (medium industrial)

TIME OF USE TARIFF	UNIT	VALUE	+VAT
Peak	EUR/kWh	0.1733	0.2044
Shoulder	EUR/kWh	0.1329	0.1568
Off-peak	EUR/kWh	0.0812	0.0958
Peak	UGX/kWh	738.00	870.84
Shoulder	UGX/kWh	565.90	667.76
Off-peak	UGX/kWh	345.70	407.93

2) Levelised cost of electricity (LCOE) is the ratio of lifetime costs to lifetime electricity generation, both discounted back to a common year using an assumed discount rate

3) Loan interest rates for medium size solar PV system in Uganda may range from 5-6% (e.g. supplier credit or export finance) on hard currency to 23% on UGX from local commercial banks. The discount rate assumption used in the model business case is based on the AFD-funded SUNREF facility available locally at the time of writing for captive power projects at about 6–7% interest on USD loans, as described in the financing section of the accompanying Developer Guide accessible at www.get-invest.eu

4) See the accompanying Developer Guide accessible at www.get-invest.eu for more details

In order to determine annual cost savings, the projected PV captive plant electricity yield was calculated and a corresponding amount of electricity from the grid (in kWh) was assumed to have been offset, less grid downtime of 1.6% per year. The cost that would have been incurred if electricity had been purchased from the grid was compared against the cost of production (LCOE) from the solar PV system.

As the LCOE for the PV system at a discount rate of up to 10% is lower than the Umeme shoulder tariff in 2017, it can be concluded that solar PV is competitive compared to the electricity tariffs of the assumed scenario. Furthermore, Solar PV systems implemented in the future in Uganda are expected to benefit from lower capital costs.

In order to confirm project attractiveness, the Net Present Value (NPV)[5] and Internal Rate of Return (IRR) as well as the payback period were calculated. The captive plant investment costs and the savings on the difference between the energy charges for grid electricity and the annual operations and maintenance (O&M) costs of the system formed the basis of the calculation. The economic decision criteria are shown next.

TABLE 5. Project indicators

ITEM	UNIT	VALUE
Project NPV	EUR	197,239
Project NPV	UGX	840,139,636
Project IRR	%	16.4
Payback period	Years	7

The office building's annual Umeme electricity bill in 2017 was broken down approximately as follows:

- **Fixed service charge:** EUR 63.12 or UGX 268,800
- **Maximum demand charge:** EUR 11,730 or UGX 49,932,000
- **Time-of-use energy charge:** EUR 216,578 or UGX 922,514,221

The total electricity bill was therefore EUR 228,371 or UGX 973 million. The assumed solar PV plant would have saved around EUR 28,600 or UGX 122 million per year, which is about 12.5% of the total electricity bill and 13.1% of the energy charges.

VALUE ADDED TAX

Value Added Tax (VAT) at 18% on equipment is not considered in this Case Study analysis as it is a throughput tax. Notice that VAT is usually not applicable on solar PV systems in Uganda if the equipment is imported as a complete package — e.g. in a container (otherwise VAT could apply on cabling and mounting equipment).

Nevertheless, in some circumstances (see the accompanying Developer Guide accessible at www.get-invest.eu) VAT may be charged on CAPEX.

SENSITIVITY TESTS AND OTHER SCENARIOS

A sensitivity analysis was performed on key parameters to test the result of a change in the variables on the economic performance of the project. The parameters were:

- The energy yield
- The investment costs
- The discount rate

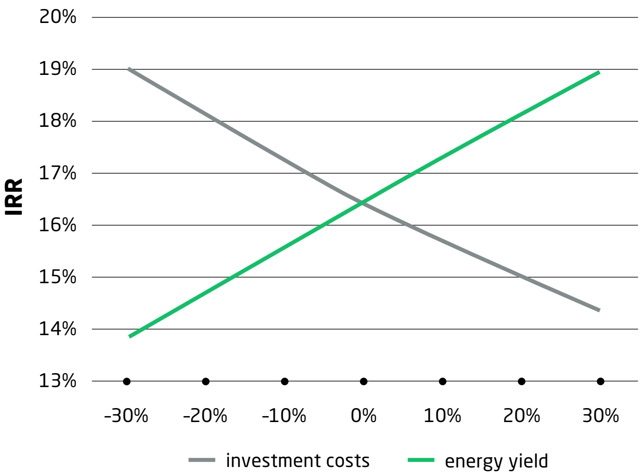
Two further scenarios were also considered:

- Electricity bill savings including VAT
- A one-off reduction in the tariff by the regulator by up to 50% in 2020 to simulate a possible outcome of lower power generation costs as new large hydro dams are commissioned in Uganda

The results of the sensitivity tests confirm the feasibility of the investment as the IRR does not drop beyond an acceptable range even if the capital costs increase or the energy yield decreases, respectively, by 15%.

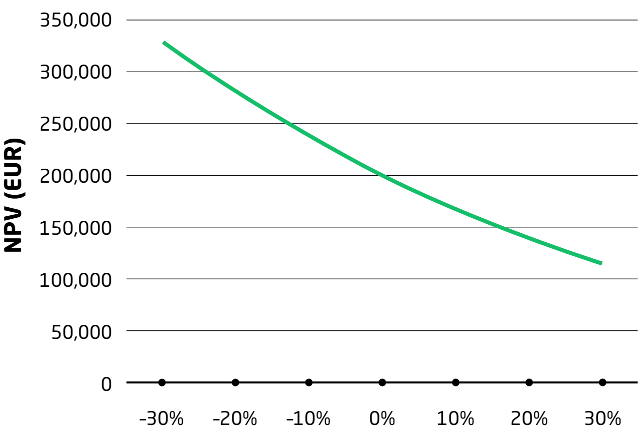
5) Net present value (NPV) is the difference between the present value of the project future cash flows and initial investment. The present value is the current worth of a future sum of money or stream of cash flows given an assumed discount rate representing the investment risk

FIGURE 2. IRR test against variation of input assumptions



In the case of the NPV, the project is still a worthwhile investment even when the discount rate increases by 30%.

FIGURE 3. NPV test against variation of discount rate



In the base case analysis, VAT on the purchase of grid electricity is not considered as a cost that can be avoided by on-site generation. However, some facility owners may consider VAT as a cost item to factor into investment decision making. In that case, the electricity bill savings are higher and the project is more attractive.

TABLE 6. Project indicators – VAT on energy charges

ITEM	UNIT	VALUE
Project NPV	EUR	275,312
Project NPV	UGX	1,172,689,857
Project IRR	%	19.3
Payback period	Years	6

The effect of electricity tariff reduction by up to 50% in 2020 (keeping the same inflation rate assumptions) is shown next:

TABLE 7. Project indicators – one-off tariff reduction in 2020

ITEM	IRR %	NPV EUR	NPV UGX
10% reduction	14.9	156,571	666,914,000
20% reduction	13.3	115,903	493,687,000
30% reduction	11.6	75,234	320,461,000
40% reduction	9.7	34,566	147,235,000
50% reduction	7.7	–6,102	–25,991,000

OTHER PROJECT BENEFITS

The solar PV captive power plant may also provide additional monetary and non-monetary benefits. These include:

- **Reactive power cost savings:** The office building may be paying reactive power penalty charges due to inductive loads such as fans and a low power factor. Solar PV inverters can provide reactive power compensation, which could reduce or reverse the charges. In 2017, a reactive energy penalty of UGX 40/kVArh/month (EUR 0.0094) and reactive energy reward compensation of UGX 20/kVArh/month (EUR 0.0047) were applicable.
- **Hedge against inflation:** The solar PV system provides reliable electricity production at almost constant prices over many years compared to utility energy charges that are subject to inflation. Even if the OPEX is also subject to inflation, its impact on the economic performance is low.

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ABOUT GET.INVEST MARKET INSIGHTS

The first series of GET.invest Market Insights are published in early 2019 covering four renewable energy market segments in three countries, namely: renewable energy applications in the agricultural value-chain (Senegal), captive power (behind the meter) generation (Uganda), mini-grids (Zambia) and stand-alone solar systems (Zambia).

Each Market Insight package includes **a)** a 'how to' Developer Guide, **b)** Model Business Cases and **c)** Case Studies. The Developer Guide enables the reader to navigate the market and its actors, to understand the current regulatory framework and lays down the step-by-step process of starting a new project/business. The Model Business Case analyses project economics and presents hypothetical, yet realistic, investment scenarios. It hence indicates the criteria for a viable project/business to enable the reader to identify the most cost-effective project/business opportunities. The Case Study analyses the viability of operational or high-potential projects/businesses to highlight lessons learnt and industry trends.

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ABOUT GET.INVEST

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GET.invest is supported by the European Union, Germany, Sweden, the Netherlands, and Austria, and works closely with initiatives and industry associations in the energy sector.

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