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Mobilising Renewable Energy Investments

Uganda: Captive Power

Case Study: 30 kWp + 40 kWp Diesel-Integrated Solar PV System at a Flower Farm

SITUATION DESCRIPTION

This project Case Study investigates the feasibility of a solar PV system investment at a flower farm near Entebbe, Uganda. The flower farm is representative of a number of similar agribusinesses with daytime loads and diesel back-up generators that have sufficient space to install such a solar PV plant to help save on electricity costs.

The main consumers of electricity at the farm include:

— Water pumps (35–40% of energy)
— Compressors (for cooling)
— Fans

The flower farm is supplied with electricity by Umeme as a tariff code 20 (medium industrial) customer. The maximum power demand is about 90–100 kW. Annual electricity needs of the flower farm are estimated to be 436,000 kWh. Two diesel back-up generators, of 110 kVA and 200 kVA capacity, are installed at the site. The daily grid downtime is about 10%. The facility operates one shift from 8:00 am–5:00 pm, 7 days a week. Most operations occur during the "shoulder" tariff period, which is reflected in the electricity load (21% during peak, 55% during shoulder, 24% during off peak period).

PV SYSTEM CONFIGURATION

In 2015, a 30 kWp solar PV system was installed at the flower farm. The system does not include battery storage and is modelled for self-consumption only (no surplus electricity to feed into the grid). Electricity outages do not have an effect on the solar PV system's electricity output as the PV installation can synchronize to the diesel generator. Prior to the installation of the PV system, it is estimated that grid electricity supplied 90% of the flower farm's annual load while the diesel generators covered the remaining 10%. In this Case, it is assumed that 90% of PV production replaces grid electricity and 10% replaces diesel. Both the existing 30 kWp system (since 2015) and an assumed capacity increase of 40 kWp (in 2018) are assessed in the case study.

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 the region. The proposed solar PV plant has the following characteristics:

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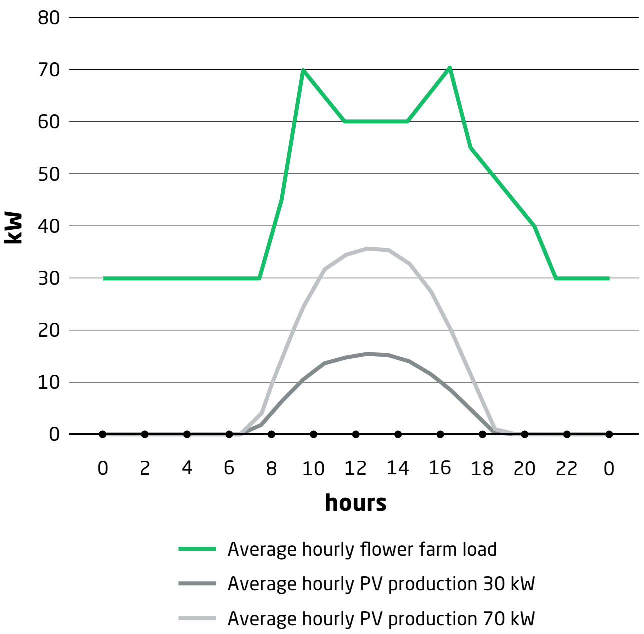
TABLE 1. Solar PV system characteristics

PARAMETER	UNIT	VALUE
Irradiation at 10° tilt	kWh/m²/y	1,928
Approximate yield	kWh/kW/y	1,418
System size (current)	kWp	30
System size (additional)	kWp	40
Annual grid outage time	%	10
Annual generation year 1 (current 30 kW system)	kWh	42,525
Annual generation year 1 (additional 40 kW capacity)	kWh	56,700
Annual degradation	%	0.5
Development & construction time	month	6
Lifetime	year	25

The impact of system degradation, system losses, temperature, grid outages, cloud cover and panel soiling is accounted for on the energy yield. The average PV output (kW) over 24 hours is shown in comparison to the flower farm's load for the existing installation and the additional capacity.

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



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.

CAPITAL AND OPERATING COSTS

Capital expenditure (CAPEX) for the existing system installed in 2015 has been provided by the farm. The estimated costs for the additional capacity considered for 2018 are based on project experience in Uganda and East Africa in 2017. A UGX-EUR exchange rate of 0.000235 is used.

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

TABLE 2. CAPEX & annual OPEX

SYSTEM	UNIT COST	PROJECT COST	
	EUR/kWp	**EUR**	**UGX**
Existing installation	2,200	66,244	282,166,000
Additional capacity	1,400	56,000	238,532,000
O&M costs	1.50%	1,834	7,810,000

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.

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 at 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 calculating the 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 year of initial investment is 2015. Twenty-five years are considered in the analysis with operations starting in 2016. The assumed year of plant extension is 2018. The division of the present value of costs by the present value of electricity production results in an LCOE as presented in the tables for different discount rates for the existing plant (30 kWp) and the expansion scenario (40 kWp).

TABLE 3. Levelised cost (30 kWp existing plant)

ITEM	EUR/kWh	UGX/kWh
LCOE at 8% discount rate	0.187	798.28
LCOE at 10% discount rate	0.212	903.89
LCOE at 12% discount rate	0.238	1015.46
LCOE at 14% discount rate	0.266	1131.78

TABLE 4. Levelised cost (40 kWp additional capacity)

ITEM	EUR/kWh	UGX/kWh
LCOE at 8% discount rate	0.122	518.67
LCOE at 10% discount rate	0.137	584.29
LCOE at 12% discount rate	0.153	653.52
LCOE at 14% discount rate	0.170	725.75

COMPARISON TO ACTUAL ELECTRICITY COSTS

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

Due to fluctuations in the output of the PV system, it is not expected that the estimated 90 kVA maximum demand of the farm that is met by grid power can be offset, which means that the monthly maximum demand charge (EUR 3.91 or UGX 16,644 per kVA per month) cannot be reduced.

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. A very 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.

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 this 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

TABLE 5. 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

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.

In order to determine annual cost savings, the projected PV plant electricity yield was calculated. As indicated earlier, it was assumed that 90% of the PV production offsets grid electricity and 10% offsets diesel generators. The cost that would have been incurred if electricity had been purchased from the grid or if electricity had been generated with the diesel units was compared against the cost of production from the solar PV system.

The LCOE are in the first years higher than the Umeme shoulder tariff, but as the tariff is assumed to increase due to inflation, the PV LCOE becomes more competitive. At the same time, PV systems implemented in the future in Uganda are expected to benefit from lower capital costs further improving the commercial viability. In this case, the 40 kWp expansion assumed in 2018 has a 35% lower LCOE (EUR 0.122/kWh) than that of the existing 30 kWp installation from 2015 (EUR 0.187/kWh).

In order to confirm project attractiveness, the Net Present Value (NPV)[5] and Internal Rate of Return (IRR) as well as the simple payback period were calculated. The captive plant investment costs and the savings on the difference between the energy charges for grid electricity and diesel generation and the annual operations and maintenance (O&M) costs of the system were the basis of the calculation. The decision criteria are shown for the existing plant, and the capacity addition with the base year 2015 as year of first investment to make results comparable.

TABLE 6. Project indicators (30 kWp existing plant)

ITEM	UNIT	VALUE
Project NPV	EUR	13,350
Project NPV	UGX	56,862,867
Project IRR	%	10.1
Payback period	Years	11

TABLE 7. Project indicators (40 kWp new capacity)

ITEM	UNIT	VALUE
Project NPV	EUR	48,997
Project NPV	UGX	208,704,137
Project IRR	%	19.0
Payback period	Years	6

The flower farm'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 4,223 or UGX 17,975,500
- **Time-of-use energy charge:** EUR 50,652 or UGX 215,753,933

The total electricity bill was therefore EUR 54,939 or UGX 234 million. The 30 kWp solar PV plant would have saved around EUR 5,000 (UGX 21 million) in grid power in 2017, which is about 9% of the total electricity bill and 10% of the energy charges and EUR 13,000 (UGX 55 million) in 2019 after expansion to 70 kWp, which is about 24% of the total electricity bill and 26% of the energy charges.

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

In addition to the savings on the electricity bill, about EUR 1,700 (UGX 7 million) of diesel consumption was offset in 2017 due to the existing plant. With the additional 40 kW capacity, about EUR 4,300 (UGX 18 million) could be saved in 2019.

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 – 40 kWp CAPACITY ADDITION

A sensitivity analysis was performed on key parameters for the 40 kWp solar PV system 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

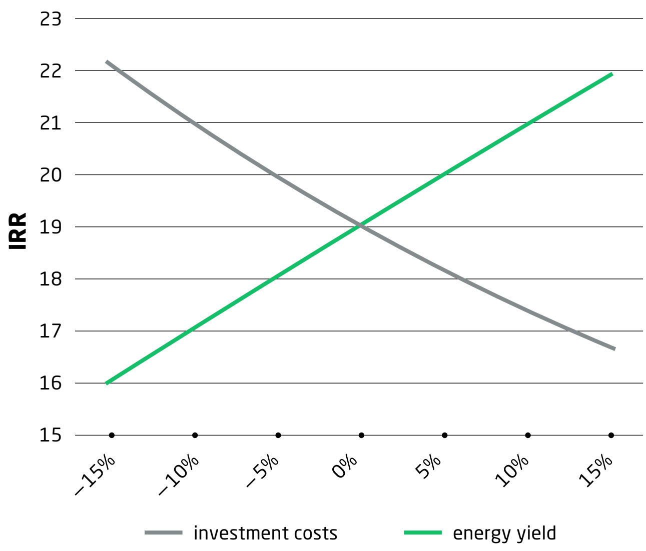
Two further scenarios were also considered:

— Electricity bill savings including VAT

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

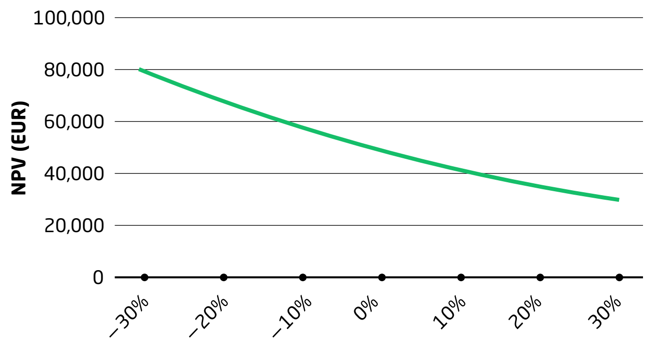
The results of the sensitivity tests confirm that the IRR does not drop beyond an acceptable range even if the capital costs increase or the energy yield decreases by 15%.

FIGURE 2. IRR test against variation of input assumptions



In addition, the NPV of the 40 kWp solar PV system remains positive even when the discount rate increases by 30% to 10.4%.

FIGURE 3. NPV test against variation of the 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 8. Project indicators – VAT on energy charges

ITEM	UNIT	VALUE
Project NPV	EUR	62,351
Project NPV	UGX	265,582,909
Project IRR	%	21.6
Payback period	Years	5

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

TABLE 9. Project indicators – one-off tariff reduction in 2020

ITEM	IRR %	NPV EUR	NPV UGX
10% reduction	17.7	42,088	179,274,000
20% reduction	16.3	35,179	149,844,000
30% reduction	14.9	28,270	120,415,000
40% reduction	13.4	21,360	90,985,000
50% reduction	11.8	14,451	61,555,000

OTHER PROJECT BENEFITS

The solar PV captive power plant on the site of a flower farm provides additional economic and non-monetary benefits. These include:

— **Reactive power cost savings:** The flower farm may be paying reactive power penalties 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 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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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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