GET.invest
Mobilising Renewable Energy Investments

Zambia: Solar PV and Hydro Mini-Grids

Model Business Case: Hydro Mini-Grid for Rural Electrification

INTRODUCTION

This Model Business Case analyses the financial feasibility of an off-grid mini-hydropower plant supplying a hypothetical community in rural Zambia where national grid extension is not foreseen. The analysis considers the potential sale of electricity to five customer types: households, business entities, hammer mills, schools, and health centres. It is assumed that a private developer will invest in the project and be responsible for the implementation of both the plant and the associated transmission and distribution grid, and for the commercial operation of the system. The latter includes the operation and maintenance of the hydro-power plant, maintenance of the mini-grid (transmission, distribution, and connections), and the sale of electricity to consumers.

Being a generic project, key features of a hydropower site — such as hydrology and layout — cannot be defined. For this case, in order to create a generic example, it is assumed that there are no site-specific limitations to obtaining the required power output and energy production to supply the mini-grid. This means that:

- Power output will be as required from the demand forecasting;
- The scheme is able to provide the required power output all year round, which in a real case would mean that the design flow is lower than the minimum flows available in the river or stream every hydrological year.

The model was prepared considering: **a)** load assumptions from the 2008 Rural Electrification Master Plan (REMP) study in Zambia; **b)** capital expenditure (CAPEX) and operations and maintenance (O&M) costs based on international reference cost curves from the International Renewable Energy Agency (IRENA) and local input; **c)** country specific parameters such as tax policy, and; **d)** parameters such as expected commercial debt terms for mini-hydro developers in Zambia.

GET.invest is supported by

European Union · german cooperation DEUTSCHE ZUSAMMENARBEIT · Sweden Sverige · Ministry of Foreign Affairs of the Netherlands · AUSTRIAN DEVELOPMENT COOPERATION

At the time of writing (mid 2018), there was no specific comprehensive regulatory[1] framework for mini-grids. However, a combined generation, distribution and supply licence can be obtained from the regulator (Energy Regulation Board — ERB) as part of a light-handed approached. Mini-grids will also need to adhere to the 2013 Grid Code and 2016 Distribution Grid Code as well as various technical standards. There is no policy or regulation in place to address the situation where the national grid arrives at a private mini-grid site. The Government of Zambia and development cooperation partners such as the AfDB, EU Delegation, Sida, and the World Bank Group are working to improve the enabling environment for off-grid energy access.

In addition, at the time of writing, there were no tender procedures for mini-grid sites in Zambia. Private developers are able to identify and secure sites for mini-grids as they see fit. However, there are uncertainties around which sites are being targeted for electrification by public entities. A National Electrification Strategy under development that should be completed by 2019 will help address this issue.

For land acquisition, developers can interact with the Water Resources Management Authority (WARMA) and the Ministry of Lands and Natural Resources. In principle, Land for a mini-grid can be acquired if a developer meets certain conditions, such as being a permanent resident, being a company 75% owned by Zambians or being an investor under the Zambia Development Agency Act.

TARGET AUDIENCE

— **Project developers**, who may be interested in over 60 MW of small hydropower estimated potential to serve part of Zambia's more than 2 million off-grid households

— **Potential investors**, who may be interested to finance private renewable energy mini-grids

TECHNOLOGY OVERVIEW

Annex A provides more details.

ASSUMPTIONS AND MAIN PARAMETERS

Customers and demand

A population of a relatively large community of approximately 16,000 people (2,400 households) was considered. The model was prepared using load assumptions from the REMP[2] as well as data collected during a field mission in Zambia mid-2018. The customer and demand characteristics shown in **Table 1** were used for year 19 of mini-grid operations, being the year when maximum demand was reached for the purposes of mini-grid system sizing.

TABLE 1. Hydropower mini-grid customers and demand – year 19

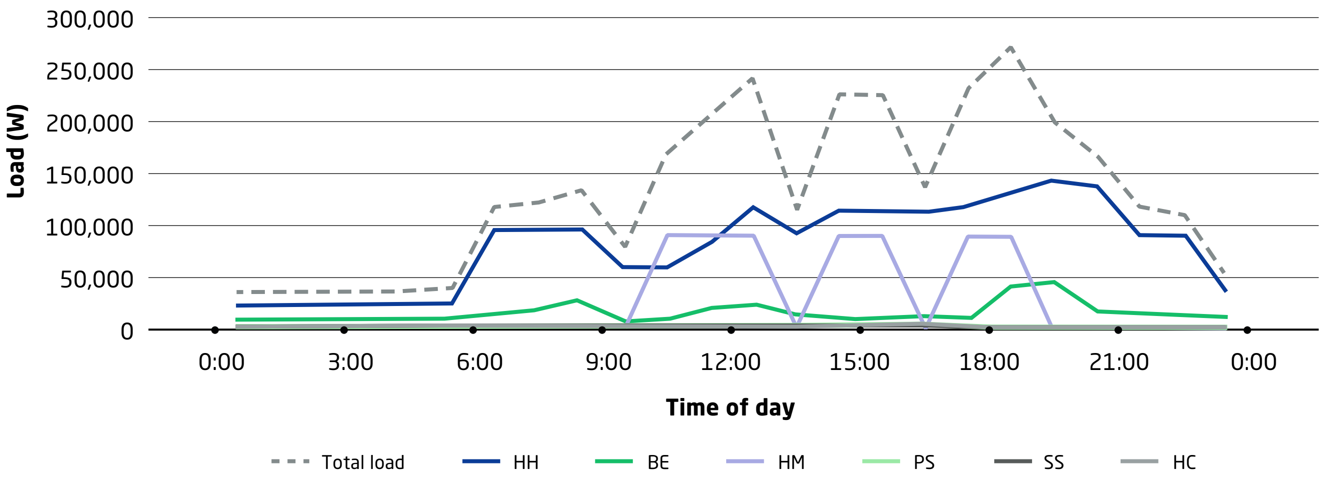
CUSTOMER TYPE	VALUE	DEMAND PER CUSTOMER	
		Max load (kW)	Average daily consumption (kWh)
Household (HH)	1,200	0.12	1.6
Small business (BE)	90	0.5	4.2
Hammer mill (HM)	6	15	105
Primary school (PS)	6	0.35	5.1
Secondary school (SS)	6	1.05	14.9
Health centre (HC)	6	0.85	13.3

Figure 1 presents an overview of the estimated load profile for the various customers served by the plant in the same year.

1) For a comprehensive summary of energy sector regulations and licensing in Zambia, please consult the accompanying Developer Guide; accessible at www.get-invest.eu

2) Rural Electrification Authority (2008) Rural Electrification Master Plan: 2009-2030. Link: www.rea.org.zm/about-us/remp/page.html – accessed 03/01/2019

FIGURE 1. Day load forecast for customers of the hydro mini-grid – year 19[3]



Given the anticipated load profile, the hydropower plant is estimated to have a power capacity of 272 kW, and a maximum annual energy demand of 1.15 GWh in year 19. It is assumed that the energy production matches the energy demand, which results in a load factor of 48%.

The forecasted demand is modelled assuming that the connection rates at the beginning of the operation are:

— 25% of total households, with only 50% of all households being connected by year 19;

— All (100%) public sector consumers;

— 50% of the assumed hammer mills;

— 60% of the businesses/small shops.

Hence, at the first year of operation, energy sales equal 70% of the forecasted demand for the project lifetime, or 0.79 GWh. For the remaining years of operation, energy sales were forecasted at 5% annual growth until the sixth year, and 1.9% annual growth until year 19.

System parameters

The main mini-grid system parameters are summarised in **Table 2**. A 33 kV distribution network of 7 km was assumed to deliver electricity to customers.

TABLE 2. Hydropower mini-grid system parameters

ITEM	UNIT	VALUE
Generator installed capacity	kW	272
Total connections year 1	–	714
Total connections year 19	–	1,314
Annual demand growth year 2–6	%	5
Annual demand growth year 7–19	%	1.9
Generation and consumption year 1	GWh/year	0.79
Generation and consumption year 19	GWh/year	1.15
Load factor year 19	%	48
33 kV distribution network	km	7

3) Note: HH = household, BE = business entity, HM = hammer mill, PS = primary school, SS = secondary school, HC = health centre

Investment and operating costs for the hydropower plant and for the distribution network are provided in Table 3. These were estimated based on average costs for hydropower plants published by IRENA[4] and on data provided by a developer in Zambia. Considering the size and remote location of the plant, a relatively high CAPEX of EUR 4,000/kW was assumed (for civil works, the penstock, turbine, generator, powerhouse and substation). Annual OPEX for the hydropower plant was assumed at 4% of CAPEX. The costs for the 33 kV distribution network were assumed based on benchmarks received from a hydropower operator in rural Zambia. Network OPEX was estimated at 6% of network CAPEX.

Additional development costs (i.e., other costs) capitalised into the project — including costs for studies and design, supervision, household connections, and contingency (10%) — were estimated at about EUR 410,000, bringing the total project CAPEX to approximately EUR 1,673,300. Accounting for O&M and other costs (insurance[5] and regulatory[6]), annual OPEX during the operational period was estimated at approximately EUR 63,500.

TABLE 3. Mini-grid system CAPEX and OPEX

CAPEX ITEM	VALUE	UNIT COST	PROJECT COST	
			EUR	ZMW
Hydropower plant	272 kW	4,000 EUR/kW	1,088,400	12,963,316
33 kV line	7 km	25,000 EUR/kW	175,000	2,084,326
Subtotal	—	—	1,263,400	15,047,642
Other costs	—	—	409,892	4,881,993
Total cost	**—**	**—**	**1,673,292**	**19,929,635**

CAPEX ITEM	VALUE	UNIT COST	ANNUAL COST	
			EUR	ZMW
Hydropower plant	272 kW	4% plant CAPEX	43,536	518,533
33 kV line	7 km	6% line CAPEX	10,500	125,060
Subtotal	—	—	54,036	643,592
Other costs	—	—	9,467	112,752
Total cost	**—**	**—**	**63,503**	**756,344**

In addition, the mini-grid is expected to incur a cost of EUR 100 for each new customer connection. Furthermore, electro-mechanical (E&M) equipment is assumed to require an overhaul in year 19 of operations at 50% of the initial cost of the powerhouse and substation E&M equipment (EUR 334,600).

Mini-grid retail tariff determination

The growth of electricity sales was considered as described under "customers and demand" section. An average tariff was considered across all customer types. In reality, it is likely that the tariff would be differentiated per end-user category.

Zambia does not have a national uniform tariff (at the time of writing) – private mini-grids may charge different tariffs subject to regulatory approval. In principle, cost-reflective tariffs may be proposed by developers. However, the current tariff guidelines present some grey areas. Most important of these is that there is a benchmark rate of 6% return on assets and it is not clear if this is fixed or may be negotiated by private developers. In addition, while subsidised assets may be included in the revenue requirement calculation, a project is not allowed to make a return on such assets or subsidised portion thereof.

For this case, a ceiling average tariff was determined using the revenue requirement methodology described by ERB's **Electricity Tariff Determination Guidelines for Retail Customers.**[7]

4) IRENA (2012) Hydropower. Renewable Energy Technologies: Cost Analysis Series. Volume 1: Power Sector, Issue 3/5. Link: www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf - accessed 03/01/2019
5) Estimated at 1% of the CAPEX of the powerhouse and substation per year
6) Mini-grid electricity license, environmental and water use regulatory charges. For information on regulatory costs, please consult the accompanying Developer Guide, accessible at www.get-invest.eu
7) Energy Regulation Board (2015): The Electricity Tariff Determination Guidelines for Retail Customers. Link: http://www.erb.org.zm/downloads/eregulation/guidelines/electricityTariffDeterminationGuidelines.pdf – accessed 03/01/2019. Further information can be found in the accompanying Developer Guide, accessible at www.get-invest.eu

Value Added Tax

Value Added Tax (VAT) at 16% is not considered. This is because VAT is a throughput tax and not a cost item for businesses. However, it is important to be aware that VAT may be applicable on hydro mini-grid plant and equipment. If applicable, it is possible to obtain VAT deferment on imported capital goods.[8] In addition, it should be noted that a mini-grid operator would usually need to add VAT and excise duty (at 3%) on electricity sales to customers.

Financing[9] scenarios

Three financing structures were assessed:

- **Base Case:** assumes a project that is financed only with commercial debt[10] and equity finance. A basic structure of 30% equity and 70% debt is applied
- **Option 1:** considers a project in which 25% of the capital costs are supported by viability gap funding (grant)
- **Option 2:** considers 50% of capital costs supported by viability gap funding

For each scenario:

- Equity investment is held constant, at 30% of total project investment costs;
- Viability gap funding is applied to capital expenditures, decreasing project debt requirements;
- Project debt is considered at 15% interest rate, a 2-year grace period, and 8-year repayment period.

The financial analysis was carried out using the base input data as presented in Table 3 and Table 4. The analysis assumed a tax regime that provides a five-year tax holiday for enterprises operating predominantly in rural areas, as well as a zero per cent import duty rate on capital goods and machinery for five years. The Model Business Case is based on an investment made in Euro. A two-year development and construction period has been assumed and 19 years of operation, which correspond to the expected lifetime of the electro-mechanical components of the hydropower plant

TABLE 4. Financial assumptions

ITEM	UNIT	VALUE
Interest rate	%	15
Grace period	years	2
Repayment period	years	8
Discount rate	%	16
Depreciation	years	10
Income tax	%	35
Development & construction period	years	2
Mini-grid operational lifetime	years	19
Lifetime civil	years	40
Lifetime E&M	years	19
Salvage value	%	20

FINANCIAL ANALYSIS RESULTS

The division of the present value of costs by the present value of electricity production results in a levelised cost of electricity (LCOE) for the system. In considering the LCOE for the project under each financing scenario, capital costs supported by viability gap funding were excluded, to provide an indication as to what tariff levels may make a project an attractive investment. Using a pre-tax discount rate of 16%[11], the LCOE under each scenario was found to be **EUR 0.43/kWh** (Base Case), **EUR 0.36/ kWh** (Option 1), and **EUR 0.26/kWh** (Option 2), respectively.

Applying the Revenue Requirement (RR) methodology and following the **Electricity Tariff Determination Guidelines for Retail Customers,** it was found that a project under the assumed

8) Note: At the time of writing, hydropower turbines, generators and transformers are zero-rated for customs duty. Imported steel piping and electrical cables are, respectively, subject to 15% and 25% customs duty. They may, however, be duty free if imported from COMESA or SADC countries. See the accompanying Developer Guide, accessible at www.get-invest.eu, for more details on taxes
9) Please refer to the accompanying Developer Guide, accessible at www.get-invest.eu, for more details on potential financing options
10) It is acknowledged that commercial financing conditions are currently not favourable for mini-grids in Zambia. The assessed scenarios are meant to provide the reader with a reference and comparison points

11) The discount rate is based on an assumed rate of return on equity

TABLE 5. Indicators at end-user retail tariff = EUR 0.43/kWh

SCENARIO	EQUITY	DEBT	GRANT	LCOE[1,2]	ERB MAX TARIFF	NPV[3]	IRR[3]	EQUITY IRR	MIN. DSCR	AVG. DSCR
	%	%	%	EUR/kWh	EUR/kWh	10^3 EUR	%	%		
Base Case	30	70	0	0.437	0.17	–490	6	33	1.25	1.32
Option 1	30	45	25	0.356	0.15	58	11	51	1.55	1.61
Option 2	30	20	50	0.262	0.12	666	22	83	2.16	2.28

1 = pre-corporate tax, 2 = exclusive of grant, 3 = post-tax, post-financing

scenarios may not be able to obtain regulatory approval for a tariff at LCOE because the LCOE exceeds the maximum tariff calculated using the methodology.[12] The maximum allowable tariffs as per the RR methodology were found to be **EUR 0.17/ kWh**, **EUR 0.15/kWh**, and **EUR 0.12/kWh**, respectively. As the tariff values for each scenario are well below the respective LCOE, such a project would likely need additional viability gap funding, or case-specific tariff determination with the regulator.

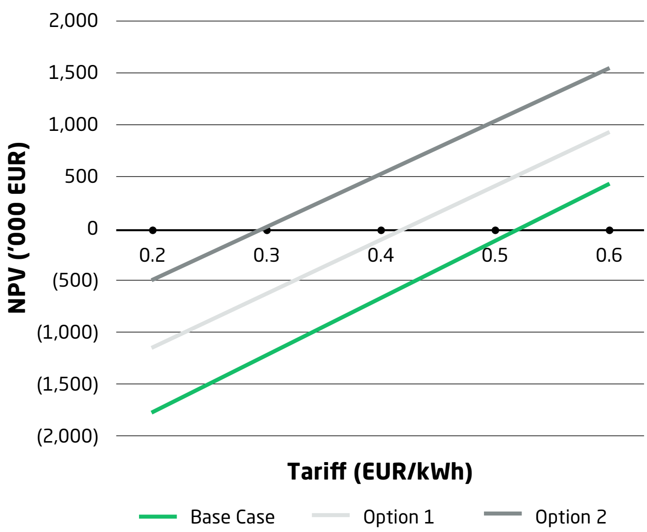
Table 5 shows the financial indicators for each scenario at an average end-user retail tariff of EUR 0.43/kWh.

As shown in **Table 5**, applying a retail tariff of EUR 0.43/kWh provides a negative net present value (NPV)[13] and a project internal rate of return (IRR) that is well below 10%[14]; however, equity IRR is attractive and the debt servicing cover ratio (DSCR) is sufficient for lenders. A 25% viability gap funding scenario (Option 1) presents a viable investment for private investors and would provide more than adequate comfort to commercial lenders concerned about macro-economic risks that might affect the project's ability to service its debt.

SENSITIVITY ANALYSIS

In order to evaluate the possibility of a project becoming more attractive to an investor, a sensitivity analysis was performed varying the retail tariff. The assumed commercial debt terms were not changed — i.e. a 15% loan with 2-year grace period and 8-year repayment period.

FIGURE 2. NPV as a function of tariff for the three modelled scenarios



12) Note: it is unclear if a tariff above that calculated using the methodology could be approved in the case where the mini-grid developer has already agreed on a higher tariff in discussions with the target community
13) 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
14) 10% is a typical rate at which a bank might find the project return sufficient to be bankable

As shown in **Figure 2**, an average tariff of approximately EUR 0.53/kWh would make the project attractive on a fully commercial basis, whereby the NPV is positive[15], equity IRR is 49%, minimum DSCR is 1.54 and average DSCR is 1.61.[16] [17] It Is uncertain whether this level of equity return and debt servicing would be agreeable through the charging of a retail tariff that is much higher than that calculated using the revenue requirement methodology. Moreover, a developer would need to closely consider abilities to pay at such a tariff. If, following a detailed demand assessment, there were sufficient commercial and industrial off-takers that could potentially subsidise a lower effective tariff for households, keeping the residential tariff below or closer to the calculated revenue requirement tariff of 0.17 EUR/kWh (Base Case), such an average tariff for the project may be possible.

On the other hand, a viability gap funding for 50% of capital costs (i.e. Option 2 in **Figure 2**), would result in a favourable investment opportunity with a retail tariff of EUR 0.30/kWh.

KEY TAKEAWAYS

— An investment decision in a hydropower mini-grid is highly dependent on the characteristics of the site (including the hydrology) and community (or communities) in question and should be taken only after a detailed assessment combining technical, commercial, social and regulatory analysis. For example, the hydropower plant should be sized taking into account both the anticipated initial load and future demand growth as well as the ability to pay for electricity.

— Based on the assumptions of the modelled scenarios, a minimum retail tariff of around EUR 0.53/kWh is needed to result in attractive financial indicators (project IRR above 10%, and equity IRR above 16% and a DSCR that is sufficient for lenders) if no viability gap funding is assumed. The retail tariff drops to EUR 0.30/kWh with a capital subsidy of around 50%.

— There are uncertainties around retail tariff determination for mini-grids in Zambia that should be clarified by developers for their circumstances. These include whether or not the 6% return on assets as per the tariff determination guidelines of the regulator is negotiable and if a tariff at a level that is higher than the calculated maximum tariff would be allowed if mini-grid customers had agreed.

15) Apart from NPV>0, an IFC (2015) rule of thumb for hydro projects is that NPV should be >25% of the required investment. In this case, NPV is 15% of the investment, leaving this particular opportunity to investor discretion

16) See Annex 2 for the results of additional tariff sensitivities

17) However, as such a tariff level would exceed the calculated maximum allowable tariff as per the revenue requirement methodology, it is uncertain if regulatory approval would be obtained

ANNEX A

Technology overview

Hydropower technology uses the combination of water pressure and flow to produce electricity by moving a turbine coupled to an electrical generator. The terminology for differentiating between various generation capacities of hydroelectric plants varies, however plants are commonly defined as pico- (<5 kW), micro- (5 to 100 kW), mini- (100 kW to 1 MW), small- (1 MW to 10 MW), and large-hydro (>10 MW).

Small-, mini-, and micro-hydro plants typically do not store water, and instead use the flow available in the river or stream. These schemes are referred to as "run-of-river" hydro schemes. The general layout for these plants consists of the following components: weir, intake, forebay, penstock, and a power house. The weir raises the water level to the intake, through which the water flows in a canal or pipe, to reach the forebay. From the forebay, the water flows through a penstock to the powerhouse, where the turbine and generator located, and where energy is produced. The forebay is typically placed a certain distance from the powerhouse, in order to create the appropriate head for the plant. A schematic illustration of the described layout is presented in **Figure 3**.

For hydroelectric plants serving localised mini-grid networks, high voltage transmission is not required, and the plant can feed directly into a medium or low voltage distribution network. If power is required a long distance from the point of generation, a higher voltage network may be required, in which case the electricity may be stepped up to the required voltage through the use of a transformer. The distribution network of hydro-based mini-grids utilise alternating current (AC).

Batteries are typically not required for hydro-based mini-grids; generators are sized in consideration of hydrology and demand requirements, with excess power either lost or potentially supplied to a national grid. Metering solutions for hydro-based mini-grids in sub-Saharan Africa vary. Legacy projects may not have metered connections, opting for flat, fixed fees (e.g. daily or monthly), or tariffs based on the number and type of connections installed per customer. More recently, with the advent of increased mobile network connectivity in rural areas, the spread of mobile money platforms, and the use of cloud-based smart metering solutions, regional hydro developers are beginning to incorporate smart metering solutions into project designs. This allows for more creative tariff designs, while also enabling remote monitoring, mobile payments, and other benefits that reduce operating expenditure (OPEX).

Hydropower plant design is site specific and, even if there are typical layouts and designs, no scheme is exactly the same. The following components particularly require site-specific inputs:

- Load assessment of the village and potential for demand stimulation;
- Physical characteristics including geology, hydrology, settlements;
- Inputs for detailed costings of civil and engineering works – including an access road.

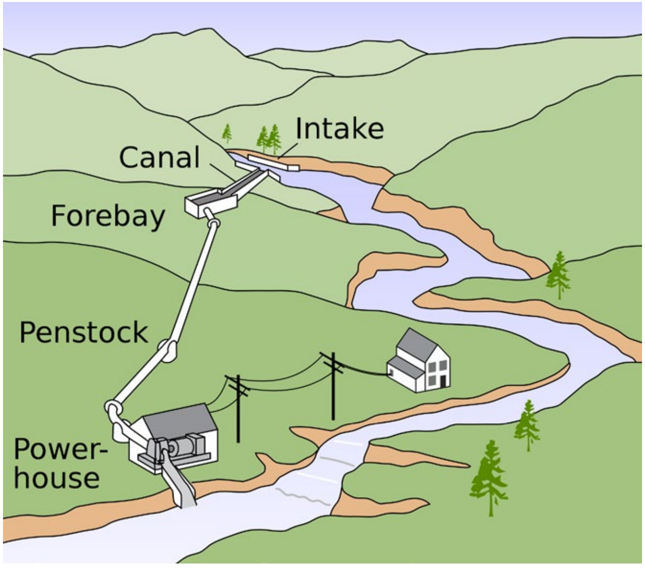


FIGURE 3. Typical layout for a small hydropower plant

ANNEX B

Results of additional tariff sensitivities

TABLE 6. Indicators at additional tariff sensitivities

TARIFF (EUR/kWh): 0.30

SCENARIO	EQUITY	DEBT	GRANT	LCOE[1,2]	ERB MAX TARIFF	NPV[3]	IRR[3]	EQUITY IRR	MIN. DSCR	AVG. DSCR
	%	%	%	EUR/kWh	EUR/kWh	10^3 EUR	%	%		
Base	30	70	0	0.437	0.17	–1,172	—	12	0.80	0.93
Option 1	30	45	25	0.356	0.15	–591	3	23	1.03	1.13
Option 2	30	20	50	0.262	0.12	17	11	47	1.50	1.56

1 = pre-corporate tax, 2 = exclusive of grant, 3 = post-tax, post-financing

TARIFF (EUR/kWh): 0.40

SCENARIO	EQUITY	DEBT	GRANT	LCOE[1,2]	ERB MAX TARIFF	NPV[3]	IRR[3]	EQUITY IRR	MIN. DSCR	AVG. DSCR
	%	%	%	EUR/kWh	EUR/kWh	10^3 EUR	%	%		
Base	30	70	0	0.437	0.17	–644	5	28	1.15	1.24
Option 1	30	45	25	0.356	0.15	–92	9	44	1.44	1.50
Option 2	30	20	50	0.262	0.12	–516	20	75	2.01	2.11

1 = pre-corporate tax, 2 = exclusive of grant, 3 = post-tax, post-financing

TARIFF (EUR/kWh): 0.53

SCENARIO	EQUITY	DEBT	GRANT	LCOE[1,2]	RR TARIFF	NPV[3]	IRR[3]	EQUITY IRR	MIN. DSCR	AVG. DSCR
	%	%	%	EUR/kWh	EUR/kWh	10^3 EUR	%	%		
Base	30	70	0	0.437	0.17	23	11	49	1.54	1.61
Option 1	30	45	25	0.356	0.15	557	17	69	1.90	1.98
Option 2	30	20	50	0.262	0.12	1,165	31	106	2.64	2.83

1 = pre-corporate tax, 2 = exclusive of grant, 3 = post-tax, post-financing

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.

GET.invest Market Insights therefore summarise a considerable amount of data that may inform early market exploration and pre-feasibility studies. It is recommended to cross-read all three products to gain a comprehensive overview. The products are accessible at www.get-invest.eu.

ABOUT GET.INVEST

GET.invest is a European programme which supports investment in decentralised renewable energy projects. The programme targets private sector business and project developers, financiers and regulators to build sustainable energy markets.

Services include project and business development support, information and matchmaking, and assistance in implementing regulatory processes. They are delivered globally and across different market segments.

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.

GET IN TOUCH

We welcome your feedback on the Market Insights by sharing any questions or comments via email at info@get-invest.eu.

DISCLAIMER

The information in this document is derived from carefully selected sources and interviews. However, GET.invest does not guarantee its accuracy or completeness and liability claims through the use of incorrect or incomplete information are excluded. This document does not necessarily represent the views of GET.invest or the countries mentioned. GET.invest does not endorse or recommend any commercial products, processes, or services mentioned in this document. This document is not intended to replace primary project and business studies. A detailed analysis for a specific project or business needs to be conducted before any investment decision.

CONTACT

GET.invest
E info@get-invest.eu
I www.get-invest.eu

Place and date: Brussels, June 2019
Photo credits: © GIZ, except where otherwise indicated