Economic and financial analysis of the investments proposed: mini-grids

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1. Summary of main results

Below we provide the main findings of the analysis, taking the point of view of (i) investors interested in producing and selling electricity and (ii) farmers investing in the mini-grid, being also the beneficiaries of power supply.

We have therefore carried out 2 separate assessments: (i) considering the market price of electricity, and the cost of connecting rural areas to the grid (resulting in an average price of $0.61 - $0.87 / kWh); (ii) considering the savings emerging from the availability of the mini-grid, with an electricity price that would allow the investment to be economically viable (on average $0.4 / kWh), and the market price of electricity in rural areas using diesel generators ($0.8 – $1 / kWh).

Energy investor:

- The IRR and NPV are positive, and the Debt Coverage Ratio (DCRE) above 1, for the mini-grid when considering the price of $0.61 - $0.87 / kWh. This shows that the mini-grid is more financially viable than bringing centralized power generation to rural areas and using fully decentralized diesel power generators. Worth noting, with any price lower than $0.8 – $1 / kWh farmers would also realize cost savings, making the investment advantageous for all economic actors.
- The IRR is 25% (with a price of $0.87 / kWh) and declines to 14% (with a price of $0.61 / kWh). The GCF contribution makes the DCR more desirable, increasing from 1.9 to 2.57 (with a price of $0.87 / kWh) or increasing from 1.39 to 1.83 (with a price of $0.61 / kWh).

Farmer investor/beneficiary:

- If a farmer cooperative were to invest in the mini-grid, they would do it in order to have affordable electricity and minimize energy spending. The price that would allow the mini-grid investment to be economically viable is $0.4 / kWh. This is the minimum price that would justify investing in the mini-grid (i.e. generating a positive IRR and NPV). On the other hand, this price would allow consumers (farmers and those working in the food value chain) to save $0.5 / kWh consumed when compared to using diesel generators.
- It results that, if we consider the investment as compared to cost savings, the IRR reaches 11% and the NPV is positive for all countries. In other words, the savings are large enough to bring the IRR to a value that is comparable to the interest rates requested by agricultural bank funds, and twice as much the rate requested by commercial banks.
- In this respect, the contribution of IGREENFIN and GCF is essential. In fact, while IRR and NPV are positive, the Debt Coverage Ratio (DCR) is smaller than 1 when considering bank rates. When using the preferential rates guaranteed by the IGREENFIN instead, the DCR is above 1, indicating economic viability for the project considering all IRR, NPV and DCR.

Further, if we carry out a more systemic analysis, and consider indirect benefits and reduction of externalities, the IRR grows to a range of 20% - 40% depending on the scenarios.

Overall we find that with the implementation of the project, the investment in mini-grids is economically viable both for all economic actors that may be interested in investing to replace reliance on diesel generators, generating both a positive return for investors and savings for consumers.

2. Overview of the Economic and Financial assessments

We have carried out two assessments for the investments proposed: one economic and one financial for solar mini-grids assessment.

- The economic assessment, presented in the form of a Cost Benefit Analysis (CBA), is broad in nature, as it includes indicators that are relevant to the projects (e.g. investment, O&M costs, revenue creation) as well as to society, even if these are not directly connected to the investment and its performance (e.g., reduction of air emissions and water pollution). For this assessment, we considered just one item and the lifetime of the investment (25 years)
- The financial assessment (PFA), which typically focuses on project outputs and activities that have direct quantifiable financial revenue generation or cost saving potential to project beneficiaries. Implied or avoided costs and benefits for other economic actors are typically not considered in the financial analysis.

The main difference between the economic and financial analysis is the addition of the cost of financing to the latter. The assessment includes the calculation of the financial Internal Rate of Return (IRR), Net-Present Value (NPV), and Benefit-to-Cost Ratio (BCR) of selected investment on solar mini-grids.

Further, we have prepared the assessments using two different perspective:

- Investors: this analysis considers investment and benefits (i.e. revenue generation from selling electricity). It reflects a situation in which an independent investors purchases the mini-grid.
- Beneficiaries: this analysis considers investment and net savings (i.e. cost differential between the amount paid when using diesel generators and the solar mini-grid). It reflects a situation where farmers and other operators in the sector may invest directly in the mini-grid to reduce electricity costs.

Finally, results are presented for "standard" and "parity" analyses. The standard analyses consider the annual revenues shown in Table 2, calculated using a fixed price per kWh of $ 0.27. Since this assessment resulted in negative NPV and IIR, an additional analysis was performed: the parity analysis is calibrated using market prices that allow to achieve the economic viability of the investments. Practically, we have identified what electricity price would make the project economically viable, considering BCR, IRR, NPV and Debt Coverage Ratio (DCR), with the latter considering two options for setting the interest rate (i.e. using commercial rates and the preferential rate guaranteed by the GCF project).

3. Economic and Financial analyses

An integrated Cost-Benefit Analysis (CBA) and a Project Finance Assessment (PFA) of solar mini-grids was carried out for five countries, Burkina Faso, Ghana, Ivory Coast, Mali and Senegal are economically viable. Starting from the assumption of 1 solar mini-grid being subject to the implementation of the investment, we have then customized the models to analyze the outcomes of the total investments by country, for each VC, and for the debt-to-coverage ratio of three potential beneficiaries (farmers organizations – FOs -, MSME and cooperatives).

CBA is a "pre-investment tool" that can facilitate investment decisions (IFAD, 2015). Since costs and benefits of investments often do not occur at the same time, with costs usually preceding benefits, the comparison is not straightforward, especially in the agricultural sector. The CBA can provide solid indicators to support decision-making as well as suggesting the best alternatives for different stakeholders, allowing to compare projects with one another using the same underlying framework of analysis.

In order to capture the full range of outcomes generated by a mini-grid investment, we have expanded the boundaries of traditional CBAs, going beyond direct costs and benefits. In fact, the CBAs presented in this study can be considered "integrated" or "extended" in that they also include an economic valuation of indirect and induced project outcomes, often labeled as "externalities". The CBA, therefore, includes project investments and operation and maintenance cost, resulting in indirect benefits from the implementation of the project (e.g. additional incomes) as well as added benefits (e.g. additional revenue generation). The CBAs provided in this assessment, therefore, estimate the societal value of the project, in alignment with the many benefits that climate-resilient and low emission projects generate.

The PFA focuses instead on the performance of the investment, considering initial investments and operation and management costs (in the form of cash flow outlays), and revenues (in the form of cash flow inflows). It further considers the cost of financing and the desired return on equity investment. Practically, it calculates the net present value (NPV), the internal rate of return (IRR) of the project, and the benefit to cost ratio, to mention three of the main indicators.

The NPV can be defined as the sum of expected costs of the investment are deducted from the discounted value of the expected revenues (or benefits). When NPV is > 0 the project is considered viable. The IRR is defined as the discount rate (r) that produces a zero NPV. It represents the maximum interest rate that a project could face and still be profitable. The project is considered viable when IRR is > r. The benefit-to-cost ratio represents the ratio of the present value of benefits to the present value of costs over the period considered. If it is ≥ to 1 then the project is viable.

For each country one discount rate and different interest rates are considered. The discount rate is calculated as the weighted average cost of capital (WACC), considering the cost of capital and the return on equity. The specific values of discount rates of the investment for each country are shown in Table 1, as chosen by IFAD. The values under "Commercial Banks Funds or MFIs" were used in the analyses that considered the GCF support, while the values under "Agricultural Banks Funds" were used in the analyses that do not consider GCF support.

Country	Interest Rate Local Currency			
	Interest Rate US$			
	GCF-IGREENFIN	Agricultural Banks Fund	Commercial Banks Fund or MFIs	Average final interest rate to end users
Burkina Faso	0%	12.0%	5%	**5%**
Côte d'Ivoire	0%	12.5%	4%	**4%**
Ghana	0%	20.5%	9.5%	**9.5%**
Mali	0%	8.63%	4%	**4%**
Senegal	0%	12.5%	4%	**4%**

Table 1: interest rates applied in each country.

There is no simple rule for choosing a discount rate to compare present and future costs and benefits. Discount rates reflect our responsibility to future generations and are a matter of ethical choice, our best estimates about technological change and the well-being of people in the future. A strong case can be made for using lower discount rates for public goods and natural/ecological assets (Goldstein, 2012). A variety of discount rates, including zero and negative rates, may be used depending on the nature of the assets being valued, the period involved, the degree of uncertainty, and the scope of the project or policy being evaluated. Presenting a sensitivity analysis of benefit-cost ratios using a range of different discount rates is always recommended, in order to highlight different ethical perspectives and their implications for future generations (TEEB, 2010).

The overall budget for this activity is $49.25m with $30m provided by the GCF, $7.5m by IsDB, $5m by commercial banks, and $7m by IFAD.

3.1. Costs, direct benefits, and indirect benefits

Data for calculating the costs and direct benefits of solar mini-grids were shared by IFAD. The full description of the methodology can be found in Annex 1. Table 2 shows the monetary costs, direct benefits, and indirect benefits of each investment in each country, as well as the lifetime of the investment.

Sustainable Tree crop (Cashew) **Lifetime: 25 years**	**Units**	**Burkina Faso**	**Ghana**	**Ivory Coast**	**Mali**	**Senegal**
Costs						
Capital costs	USD/item	27,361.00	27,361.00	27,361.00	27,361.00	27,361.00
O&M annual costs	USD/item	2,736.10	2,736.10	2,736.10	2,736.10	2,736.10
Indirect benefits						
Average annual additional income generated	USD/item	3,240.00	3,240.00	3,240.00	3,240.00	3,240.00
Direct benefits						
Electricity revenues	USD/item	*changes in each scenario, depending on the price considered*				
Annual value creation (income)	USD/item	3243.54	3243.54	3243.54	3243.54	3243.54

Table 2: Solar mini-grids

3.2. Mini-grid assumptions

The cost summed for mini-grids is USD 27,361 as CAPEX, and it includes solar generation assets (panels, inverters, cables, protections, mounting system and a small storage to guarantee 1.8 days of autonomy) as well as a low voltage distribution line up to 500 m. The cost is calculated based on benchmarks for similar systems in the region and the own database of IFAD.

Annual operation and maintenance, in the amount of 10% of the CAPEX (USD 2,736 / year) include battery replacement, assumed to take place every 8 years. Practically, O&M over 8 years would amount to USD 21,888 of which USD 8,800 is the estimated cost of the battery to be replaced in 8-year intervals. It results that battery replacement is included in the O&M expenditure assumed in the analysis.

Systems are modular and each unit will be 8 kWp. In total 1800 such units will be installed across the 5 countries leading to a total installed capacity of 14.4 MWp. Electricity generation is calculated for 360 days (conservative estimates for efficient sunlight days), 5 hours daily average (consistent with average insolation data for the region), using and efficiency factor of 80% (consistent with 20% system losses). First year generation is therefore 14,400*0.8*360*5 = 20.736.000 kWh. Then consistent with solar PV technology a factor of annual performance loss of 1% on solar panels has been applied. The compilation of these data were provided in Annex 23.

The value of total emissions savings from mini-grids is estimated at 638,639 tons of CO_2. This covers the lifetime of solar mini-grids. Given that the first-year electricity generation is estimated at 20,736,000 kWh, dividing 638,639 (tons of CO_2) by 25 (lifetime in years) and by 20,736,000 (kWh) allows us to obtain the total avoided tons of CO_2 per kWh: 0.001232 tons CO_2/kWh.

Since each system can generate 8kWh*365*0.8(efficiency)*5h = 11680 kWh a year, we multiplied this value by 0.001232 tons CO_2/kWh to obtain the total avoided emission per mini-grid. We then multiplied the value of avoided carbon emissions by 40 USD including an annual increase of 2.5%. Annual monetary revenues were considered as avoided costs in the economic and financial analysis.

It is also worth noting that Baseline Emissions are the same as Emissions Reduction in this project. Formula for emissions reduction is ER = BE – PE – LE where, ER are Emission Reduction, BE are Baseline Emissions, PE are project own Emission and LE are Leakage Emission. IGREENFIIN is not having own emissions: the project does not intend to put in place hybrid mini-grids, rather systems that will generate electricity using solely solar. There are no plans to burn biomass, on the contrary such unsustainable agricultural practices will be changed. There is also no leakage. Therefore BE = ER.

3.3. Income Tax

The following values of income tax have been used in the assessment. These values were provided by IFAD.

- Burkina Faso personal income tax rate 12-15% (we used 13.5%)
- Ghana personal income tax rate 30%
- Ivory Coast personal income tax rate 60%
- Mali personal income tax rate 3%
- Senegal personal income tax rate between 20-30% (we used 25%)

4. Comparative analysis – grid connection: sales price of $0.61 – 0.87 / kWh

4.1. Results: aggregate performance - Investors

The results of the analysis performed for solar mini-grids are shown from Table 3 to Table 9 including the analysis of one solar mini-grid being supported and the aggregated results for the entire program. The analysis of each investment considers the lifetime of the intervention. The analysis also considered the discount rates with GCF and Bank contribution, as shown in Table 1.

In this assessment we consider the price of electricity sold via centralized generation that is connected to the grid in rural areas. We use two price levels, $0.61 and $0.87 / kWh based on literature review (Mainali & Dhital, 2015; Cust, Singh, & Neuhoff, 2007). This is the result of adding the local grid-connected electricity price in urban areas ($0.27 / kWh) to the levelized cost of connecting local areas to the grid.

Overall, the results are positive, indicating that the investments will generate value for potential investors when the electricity is sold at a price comparable to the one of grid connected electricity, in rural areas.

The IRR is 25% (with a price of $0.87 / kWh) and declines to 14% (with a price of $0.61 / kWh). The GCF contribution makes the DCR more desirable, increasing from 1.9 to 2.57 (with a price of $0.87 / kWh) or increasing from 1.39 to 1.83 (with a price of $0.61 / kWh).

The results presented below consider the full lifetime of investments, which often goes well beyond the duration of the project (6 years). As a result, both revenues and externalities extend beyond the formal duration of the involvement of GCF. Regarding the IRR, NPV, and BCR, we also show their values when including externalities, or avoided costs (S-IRR, S-NPV, and S-IRR).

4.1.1. Solar mini-grids – GCF support

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$254,040	$100,661	$77,262	$133,328	2.17	3.02	27%	41%	4	3
Ghana	$95,764	$27,361	$254,040	$100,661	$42,687	$79,893	1.80	2.50	27%	41%	4	3
Ivory Coast	$95,764	$27,361	$254,040	$100,661	$88,611	$150,897	2.26	3.15	27%	41%	4	3
Mali	$95,764	$27,361	$254,040	$100,661	$88,611	$150,897	2.26	3.15	27%	41%	4	3
Senegal	$95,764	$27,361	$254,040	$100,661	$88,611	$150,897	2.26	3.15	27%	41%	4	3

Table 3: portfolio analysis (1 solar mini-grid) – Solar price 0.87 $/kWh

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$178,120	$100,661	$34,474	$90,540	1.52	2.37	16%	30%	4	3
Ghana	$95,764	$27,361	$178,120	$100,661	$14,039	$51,246	1.26	1.96	16%	30%	4	3
Ivory Coast	$95,764	$27,361	$178,120	$100,661	$41,182	$103,468	1.59	2.48	16%	30%	4	3
Mali	$95,764	$27,361	$178,120	$100,661	$41,182	$103,468	1.59	2.48	16%	30%	4	3
Senegal	$95,764	$27,361	$178,120	$100,661	$41,182	$103,468	1.59	2.48	16%	30%	4	3

Table 4: portfolio analysis (1 solar mini-grid) – Solar price 0.61 $/kWh

Program															
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**
Burkina Faso	$17,064,688	$10,944,444	$34,745,685	$14,632,665	$72,040,054	$44,347,525	$34,873,926	$20,023,779	38%	25%	2.81	1.65	3	4	2.81	2.81	2.81
Ghana	$12,798,516	$8,208,333	$26,059,264	$10,974,499	$54,030,041	$33,260,643	$14,087,398	$7,318,227	38%	25%	2.17	1.12	3	4	2.01	2.01	2.01
Ivory Coast	$12,798,516	$8,208,333	$26,059,264	$10,974,499	$54,030,041	$33,260,643	$30,345,903	$17,710,558	38%	25%	2.98	1.81	3	4	1.95	1.95	1.95
Mali	$17,064,688	$10,944,444	$34,745,685	$14,632,665	$72,040,054	$44,347,525	$40,461,204	$23,614,078	38%	25%	2.98	1.81	3	4	3.29	3.29	3.29
Senegal	$17,064,688	$10,944,444	$34,745,685	$14,632,665	$72,040,054	$44,347,525	$40,461,204	$23,614,078	38%	25%	2.98	1.81	3	4	2.77	2.77	2.77

Table 5: portfolio analysis (Program) - Solar price 0.87 $/kWh

Program																	
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**
Burkina Faso	$17,064,688	$10,944,444	$24,361,917	$14,632,665	$51,075,399	$23,382,869	$23,467,581	$8,617,433	27%	14%	2.32	1.16	3	4	1.95	1.95	1.95
Ghana	$12,798,516	$8,208,333	$18,271,438	$10,974,499	$38,306,549	$17,537,152	$8,878,306	$2,109,135	27%	14%	1.83	0.78	3	4	1.48	1.48	1.48
Ivory Coast	$12,798,516	$8,208,333	$18,271,438	$10,974,499	$38,306,549	$17,537,152	$20,640,945	$8,005,600	27%	14%	2.44	1.27	3	4	1.51	1.51	1.51
Mali	$17,064,688	$10,944,444	$24,361,917	$14,632,665	$51,075,399	$23,382,869	$27,521,260	$10,674,133	27%	14%	2.44	1.27	3	4	2.24	2.24	2.24
Senegal	$17,064,688	$10,944,444	$24,361,917	$14,632,665	$51,075,399	$23,382,869	$27,521,260	$10,674,133	27%	14%	2.44	1.27	3	4	1.96	1.96	1.96

Table 6: portfolio analysis (Program) - Solar price 0.61 $/kWh

4.1.2. Solar mini-grids – Banks discount rates

Onemini-grid												
Mini-grids	**Totalinvestment**	**Projectcontribution**	**Revenues generated**	**Valueofexternalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**PaybackPeriod(Years)**	**S-PaybackPeriod(Years)**
BurkinaFaso	$95,764	$27,361	$254,040	$100,661	$30,850	$61,644	1.63	2.26	27%	41%	4	3
Ghana	$95,764	$27,361	$254,040	$100,661	$8,500	$27,287	1.21	1.67	27%	41%	4	3
IvoryCoast	$95,764	$27,361	$254,040	$100,661	$28,889	$58,625	1.60	2.22	27%	41%	4	3
Mali	$95,764	$27,361	$254,040	$100,661	$47,787	$87,764	1.87	2.59	27%	41%	4	3
Senegal	$95,764	$27,361	$254,040	$100,661	$28,889	$58,625	1.60	2.22	27%	41%	4	3

Table 7: portfolio analysis (1 solar mini-grid) – Solar price 0.87 $/kWh

Onemini-grid												
Mini-grids	**Totalinvestment**	**Projectcontribution**	**Revenues generated**	**Valueofexternalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**PaybackPeriod(Years)**	**S-PaybackPeriod(Years)**
BurkinaFaso	$95,764	$27,361	$178,120	$100,661	$7,043	$37,838	1.14	1.78	16%	30%	4	3
Ghana	$95,764	$27,361	$178,120	$100,661	$(6,166)	$12,621	0.85	1.31	16%	30%	4	3
IvoryCoast	$95,764	$27,361	$178,120	$100,661	$5,885	$35,620	1.12	1.74	16%	30%	4	3
Mali	$95,764	$27,361	$178,120	$100,661	$17,054	$57,031	1.31	2.04	16%	30%	4	3
Senegal	$95,764	$27,361	$178,120	$100,661	$5,885	$35,620	1.12	1.74	16%	30%	4	3

Table 8: portfolio analysis (1 solar mini-grid) – Solar price 0.61 $/kWh

Program																	
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**
Burkina Faso	$17,064,688	$10,944,444	$34,745,685	$14,632,665	$72,040,054	$44,347,525	$13,691,413	$6,548,488	38%	25%	1.90	0.93	3	4	2.07	2.07	2.07
Ghana	$12,798,516	$8,208,333	$26,059,264	$10,974,499	$54,030,041	$33,260,643	$3,735,200	$878,144	38%	25%	1.30	0.56	3	4	1.57	1.57	1.57
Ivory Coast	$12,798,516	$8,208,333	$26,059,264	$10,974,499	$54,030,041	$33,260,643	$9,656,012	$4,527,601	38%	25%	1.85	0.90	3	4	1.48	1.48	1.48
Mali	$17,064,688	$10,944,444	$34,745,685	$14,632,665	$72,040,054	$44,347,525	$21,052,592	$11,196,165	38%	25%	2.27	1.20	3	4	2.48	2.48	2.48
Senegal	$17,064,688	$10,944,444	$34,745,685	$14,632,665	$72,040,054	$44,347,525	$12,874,682	$6,036,802	38%	25%	1.85	0.90	3	4	1.90	1.90	1.90

Table 9: portfolio analysis (Program) – Solar price 0.87 $/kWh

Program																	
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**
Burkina Faso	$17,064,688	$10,944,444	$24,361,917	$14,632,665	$51,075,399	$23,382,869	$8,184,901	$1,041,977	27%	14%	1.62	0.65	3	4	1.47	1.47	1.47
Ghana	$12,798,516	$8,208,333	$18,271,438	$10,974,499	$38,306,549	$17,537,152	$1,517,958	$(1,339,098)	27%	14%	1.14	0.39	3	4	1.14	1.14	1.14
Ivory Coast	$12,798,516	$8,208,333	$18,271,438	$10,974,499	$38,306,549	$17,537,152	$5,700,969	$572,558	27%	14%	1.58	0.63	3	4	1.21	1.21	1.21
Mali	$17,064,688	$10,944,444	$24,361,917	$14,632,665	$51,075,399	$23,382,869	$13,471,782	$3,615,355	27%	14%	1.92	0.84	3	4	1.72	1.72	1.72
Senegal	$17,064,688	$10,944,444	$24,361,917	$14,632,665	$51,075,399	$23,382,869	$7,601,292	$763,411	27%	14%	1.58	0.63	3	4	1.39	1.39	1.39

Table 10: portfolio analysis (Program) – Solar price 0.61$/kWh

5. Comparative analysis – parity, breakeven for the mini-grid

This assessment calculates revenues from electricity generation and sales based on the price that would make the project economically viable. It assumes that electricity is produced not to make profit, but to improve the economic viability of operations in the farming value chain (i.e. the electricity is sold at -levelized- cost, and avoided costs, or net savings, are accrued by consumers).

	Price increase over average national, grid price	Parity Prices (USD/kWh)	Price relative to diesel (USD/kWh)
BF	45%	0.403	-55%
GH	74%	0.483	-46%
CIV	39%	0.386	-57%
ML	39%	0.386	-57%
SN	39%	0.386	-57%

5.1. Results: aggregate performance - Investors

The results of the analysis performed for solar mini-grids are shown from Table 11 to Table 14 including the analysis of one solar mini-grid being supported and the aggregated results for the entire program. The analysis of each investment considers the lifetime of the intervention. The analysis also considered the discount rates with GCF and Bank contribution, as shown in Table 1.

Overall, the results show that the investment in mini-grids is economically viable for all countries, with positive IRR and NPV, BCR and DCR above 1 (Table 11). The performance of the investment is more mixed when considering the outcomes of the full program, but remain largely positive.

The results presented below consider the full lifetime of investments, which often goes well beyond the duration of the project (6 years). As a result, both revenues and externalities extend beyond the formal duration of the involvement of GCF. Regarding the IRR, NPV, and BCR, we also show their values when including externalities, or avoided costs (S-IRR, S-NPV, and S-IRR).

5.1.1. Solar mini-grids – GCF support

Table 11 and Table 12 show the performance of solar mini-grids. The 1item (Table 11) suggests that the investment is always positive (considering the NPV, BCR, and IRR) in all countries. On the other hand, the programme assessment (Table 12) shows negative NPVs and BCRs. These indicators are always positive if they also consider externalities. It is worth noting that the debt service coverage ratios shown in Table 12 are positive, meaning that the investors may be able to repay their investments.

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$117,578	$100,661	$354	$56,420	1.01	1.86	5%	21%	14.00	5.00
Ghana	$95,764	$27,361	$141,094	$100,661	$68	$37,275	1.00	1.70	10%	25%	10.00	5.00
Ivory Coast	$95,764	$27,361	$112,713	$100,661	$321	$62,607	1.00	1.89	4%	20%	16.00	5.00
Mali	$95,764	$27,361	$112,713	$100,661	$321	$62,607	1.00	1.89	4%	20%	16.00	5.00
Senegal	$95,764	$27,361	$112,713	$100,661	$321	$62,607	1.00	1.89	4%	20%	16.00	5.00

Table 11: portfolio analysis (1 solar mini-grid)

Program																		
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**
Burkina Faso	$17,064,688	$10,944,444	$16,081,461	$14,632,665	$34,357,295	$6,664,766	$14,371,678	$(478,469)	19%	4%	1.93	0.76	6	9.00	1.27	1.27	1.27
Ghana	$12,798,516	$8,208,333	$14,473,315	$10,974,499	$30,638,202	$9,868,805	$6,337,832	$(431,339)	23%	8%	1.67	0.62	5	8.00	1.22	1.22	1.22
Ivory Coast	$12,798,516	$8,208,333	$11,562,016	$10,974,499	$24,760,338	$3,990,940	$12,279,862	$(355,483)	19%	3%	1.97	0.80	6	9.00	1.14	1.14	1.14
Mali	$17,064,688	$10,944,444	$15,416,022	$14,632,665	$33,013,783	$5,321,254	$16,373,150	$(473,977)	19%	3%	1.97	0.80	6	9.00	1.33	1.33	1.33
Senegal	$17,064,688	$10,944,444	$15,416,022	$14,632,665	$33,013,783	$5,321,254	$16,373,150	$(473,977)	19%	3%	1.97	0.80	6	9.00	1.25	1.25	1.25

Table 12: portfolio analysis (Program)

5.1.2. Solar mini-grids – Banks discount rates

Table 13 and Table 14 show the performance of solar mini-grids. Both the 1item (Table 13) and programme (Table 14) investments show similar results for all countries, where the NPV and the BCR are always negative. These indicators are always positive if externalities are considered. Finally, it is worth noting that the debt service coverage ratios shown in Table 14 are always negative except the one for Mali, meaning that in that country the investors may be able to repay their investments.

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$117,578	$100,661	$(11,941)	$18,854	0.76	1.39	5%	21%	14.00	5.00
Ghana	$95,764	$27,361	$141,094	$100,661	$(13,319)	$5,468	0.67	1.13	10%	25%	10.00	5.00
Ivory Coast	$95,764	$27,361	$112,713	$100,661	$(13,934)	$15,801	0.71	1.33	4%	20%	16.00	5.00
Mali	$95,764	$27,361	$112,713	$100,661	$(9,424)	$30,554	0.83	1.56	4%	20%	16.00	5.00
Senegal	$95,764	$27,361	$112,713	$100,661	$(13,934)	$15,801	0.71	1.33	4%	20%	16.00	5.00

Table 13: portfolio analysis (1 solar mini-grid)

Program																			
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**		
Burkina Faso	$17,064,688	$10,944,444	$16,081,461	$14,632,665	$34,357,295	$6,664,766	$3,793,776	$(3,349,148)	19%	4%	1.40	0.43	6	9.00	0.98	0.98	0.98		
Ghana	$12,798,516	$8,208,333	$14,473,315	$10,974,499	$30,638,202	$9,868,805	$436,609	$(2,420,447)	23%	8%	1.05	0.31	5	8.00	0.92	0.92	0.92		
Ivory Coast	$12,798,516	$8,208,333	$11,562,016	$10,974,499	$24,760,338	$3,990,940	$2,293,593	$(2,834,818)	19%	3%	1.35	0.40	6	9.00	0.85	0.85	0.85		
Mali	$17,064,688	$10,944,444	$15,416,022	$14,632,665	$33,013,783	$5,321,254	$6,940,710	$(2,915,717)	19%	3%	1.61	0.53	6	9.00	1.06	1.06	1.06		
Senegal	$17,064,688	$10,944,444	$15,416,022	$14,632,665	$33,013,783	$5,321,254	$3,058,123	$(3,779,757)	19%	3%	1.35	0.40	6	9.00	0.91	0.91	0.91		

Table 14: portfolio analysis (Program)

5.2. Results: aggregate performance – Beneficiaries

The results of the analysis performed for solar mini-grids are shown in Table 15 and Table 18 including the analysis of one solar mini-grid being supported and the aggregated results for the entire program. The analysis of each investment considers the lifetime of the intervention, and specifically the investment required as compared to the net energy cost savings when considering diesel generators and solar mini-grid.

Overall, the results are positive, and show that the energy cost savings accrued year after year allow to pay back the investment and the loan. The contribution of GCF results to be essential for having DCR above 1, justifying the involvement of GCF and partners in providing preferential loan conditions.

The results presented below consider the full lifetime of investments, which often goes well beyond the duration of the project (6 years). As a result, both revenues and externalities extend beyond the formal duration of the involvement of GCF. Regarding the IRR, NPV, and BCR, we also show their values when including externalities, or avoided costs (S-IRR, S-NPV, and S-IRR).

5.2.1. Solar mini-grids – GCF support

Table 15 and Table 16 show the performance of solar mini-grids. The 1item assessment (Table 15) indicates that the investment is profitable in three countries (Ivory Coast, Mali, and Senegal) where the BCR, NPV, and IRR are always positive, thanks to the low interest rates in these countries. This is also shown in the programme assessment (Table 16) although the BCR is always slightly negative. However, Table 16 also indicates that the debt service coverage ratios are always positive in all the considered countries except Ghana, meaning that the beneficiaries will be able to repay their debt in at least four out of five countries. Ghana is characterized by higher interest rates when compared with other countries, reason for seeing this difference in results.

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$116,022	$100,661	$(523)	$55,542	0.99	1.84	5%	21%	15.00	8.00
Ghana	$95,764	$27,361	$92,506	$100,661	$(18,266)	$18,941	0.66	1.36	-1%	17%	Negative	12.00
Ivory Coast	$95,764	$27,361	$120,887	$100,661	$5,427	$67,713	1.08	1.97	6%	22%	13.00	8.00
Mali	$95,764	$27,361	$120,887	$100,661	$5,427	$67,713	1.08	1.97	6%	22%	13.00	8.00
Senegal	$95,764	$27,361	$120,887	$100,661	$5,427	$67,713	1.08	1.97	6%	22%	13.00	8.00

Table 15: portfolio analysis (1 solar mini-grid)

Program																
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**
Burkina Faso	$17,064,688	$10,944,444	$15,868,594	$14,632,665	$33,927,520	$6,234,990	$14,137,848	$(712,299)	19%	4%	1.92	0.75	8	16.00	1.26	1.26	1.26
Ghana	$12,798,516	$8,208,333	$9,489,226	$10,974,499	$20,575,409	$(193,988)	$3,004,094	$(3,765,077)	16%	-1%	1.46	0.41	9	Negative	0.81	0.81	0.81
Ivory Coast	$12,798,516	$8,208,333	$12,400,525	$10,974,499	$26,453,274	$5,683,877	$13,324,788	$689,443	20%	5%	2.03	0.86	7	14.00	1.18	1.18	1.18
Mali	$17,064,688	$10,944,444	$16,534,034	$14,632,665	$35,271,032	$7,578,502	$17,766,383	$919,257	20%	5%	2.03	0.86	7	14.00	1.44	1.44	1.44
Senegal	$17,064,688	$10,944,444	$16,534,034	$14,632,665	$35,271,032	$7,578,502	$17,766,383	$919,257	20%	5%	2.03	0.86	7	14.00	1.34	1.34	1.34

Table 16: portfolio analysis (Program)

5.2.2. Solar mini-grids – Banks discount rates

Table 17 and Table 18 show the performance of solar mini-grids. Both the 1item (Table 17) and programme (Table 18) investments show similar results for all countries, where the NPV and BCR are always slightly negative when excluding externalities, and positive when including them.

The DCR is also generally negative, with exception of Mali. Overall, when comparing these results with the ones presented in section 5.2.1 it becomes evident that GCF support is essential to make this investment economically viable.

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$116,022	$100,661	$(12,429)	$18,366	0.75	1.38	5%	21%	15.00	5.00
Ghana	$95,764	$27,361	$92,506	$100,661	$(22,705)	$(3,918)	0.44	0.90	-1%	17%	NEGATIVE	6.00
Ivory Coast	$95,764	$27,361	$120,887	$100,661	$(11,458)	$18,278	0.76	1.38	6%	22%	13.00	5.00
Mali	$95,764	$27,361	$120,887	$100,661	$(6,115)	$33,863	0.89	1.62	6%	22%	13.00	5.00
Senegal	$95,764	$27,361	$120,887	$100,661	$(11,458)	$18,278	0.76	1.38	6%	22%	13.00	5.00

Table 17: portfolio analysis (1 solar mini-grid)

Program																			
Mini-grids	Total investment	Project contribution	Revenues generated	Value of externalities	Undiscounted net benefit with externalities	Undiscounted net benefit without externalities	S-NPV	NPV	S-IRR (lifetime)	IRR (lifetime)	S-Benefit to cost ratio (lifetime) / discounted	Benefit to cost ratio (lifetime) / discounted	S-Payback Period (Years)	Payback Period (Years)	Debt Service Coverage Ratio - Farmers organizations	Debt Service Coverage Ratio - MSMEs	Debt Service Coverage Ratio - COOPERATIVES
Burkina Faso	$17,064,688	$10,944,444	$15,868,594	$14,632,665	$33,927,520	$6,234,990	$3,680,893	$(3,462,032)	19%	4%	1.39	0.42	6	9.00	0.96	0.96	0.96
Ghana	$12,798,516	$8,208,333	$9,489,226	$10,974,499	$20,575,409	$(193,988)	$(982,392)	$(3,839,449)	16%	-1%	0.95	0.20	7	11.00	0.63	0.63	0.63
Ivory Coast	$12,798,516	$8,208,333	$12,400,525	$10,974,499	$26,453,274	$5,683,877	$2,719,429	$(2,408,981)	20%	5%	1.38	0.43	5	8.00	0.90	0.90	0.90
Mali	$17,064,688	$10,944,444	$16,534,034	$14,632,665	$35,271,032	$7,578,502	$7,756,930	$(2,099,497)	20%	5%	1.65	0.57	6	9.00	1.14	1.14	1.14
Senegal	$17,064,688	$10,944,444	$16,534,034	$14,632,665	$35,271,032	$7,578,502	$3,625,905	$(3,211,975)	20%	5%	1.38	0.43	6	9.00	0.97	0.97	0.97

Table 18: portfolio analysis (Program)

5.3. Sensitivity analysis

The sensitivity analysis shown in this section considers different alternative scenarios, as shown in Table 19. Only the results with the discount rates derived from the GCF intervention have been considered.
The first scenario is the "base case" scenario, where assumptions of costs and revenues have not been modified. In the second one, the "parity" scenario, we increased the price of electricity until a positive NPV is reached. Finally, the third one is similar to the parity scenario, but it also includes a 20% reduction of revenues (assuming that demand is on average 20% less than capacity) and estimates the tariff that would still allow the project to break even. Only the 1 solar mini-grid assessment has been considered.

	Base case	Parity scenario	Parity scenario including a decline (-20%) of electricity prices
	NPV	NPV	NPV
Burkina Faso	$(20,211)	$353.81	$262.41
Ghana	$(22,574)	$68.04	$190.43
Ivory Coast	$(19,436)	$320.75	$16.80
Mali	$(19,436)	$320.75	$16.80
Senegal	$(19,436)	$320.75	$16.80

Table 19: Sensitivity Analysis – 1 solar mini-grid

As Table 19 shows, under the base case scenario the investment is always negative. In the other scenarios, the prices of electricity (direct revenues) were increased until a positive NPV is reached. Table 20 shows the required increase of electricity prices to reach a positive NPV in both alternative scenarios.

	Parity scenario	Parity scenario including a decline (-20%) of electricity prices
	%	%
Burkina Faso	45%	81%
Ghana	74%	118%
Ivory Coast	39%	73%
Mali	39%	73%
Senegal	39%	73%

Table 20: Required increase of electricity prices to reach a positive NPV

The price increases estimate to reach a positive NPV is aligned with the values found in the literature. For example, The World Bank (2017) and IED (2013) suggest that electricity prices in Sub-Saharan countries range from 0.6 to 1.0 USD/kWh. In this study, we used 0.8 USD/kWh as the average price. This would represent more than doubling the baseline $ 0.27 per kWh tariff used as baseline assumption. As a result, our estimate of the breakeven price is lower than the price point identified in the above-cited references for all the countries analyzed.

6. Comparative analysis - farmer investor, considering investment and net savings in energy cost

6.1. Results: aggregate performance – Beneficiaries

This analysis considers investments, and compares them to the potential savings generated by the introduction of the mini-grid (calculated as the difference between the electricity cost from diesel generators and the price of the electricity generated from the solar mini-grids systems).

The results of the analysis performed for solar mini-grids are shown from Table 25 to Table 28 including the analysis of one solar mini-grid and the aggregated results for the entire program. The analysis of each investment considers the lifetime of the intervention. The analysis also considered the discount rates with GCF and Bank contribution, as shown in Table 1.

The results are positive, indicating that the investments are economically viable and can generate value for potential beneficiaries. It is worth noting that with the GCF contribution, the investments are generally more potentially profitable than the ones that use the interest rate of commercial banks (see debt coverage ratio).

Further, the results presented below consider the full lifetime of investments, which often goes well beyond the duration of the project (6 years). As a result, both revenues and externalities extend beyond the formal duration of the involvement of GCF. Regarding the IRR, NPV, and BCR, we also show their values when including externalities, or avoided costs (S-IRR, S-NPV, and S-IRR).

6.1.1. Solar mini-grids – GCF support

Table 25 and Table 26 show the performance of solar mini-grids. Both the 1item (Table 25) and programme (Table 26) investments show similar results for all countries, where the NPV, IRR, BCR are always positive, except the BCR of the program analysis of both Burkina Faso and Ghana. These indicators are always positive if they also consider externalities. It is worth noting that the debt service coverage ratios shown in Table 26 are always positive, meaning that the beneficiaries would be able to repay their debt in all the five countries considered in this study.

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$152,512	$100,661	$20,042	$76,108	1.30	2.15	11%	26%	9.00	4.00
Ghana	$95,764	$27,361	$152,512	$100,661	$4,376	$41,583	1.08	1.78	11%	26%	9.00	4.00
Ivory Coast	$95,764	$27,361	$152,512	$100,661	$25,184	$87,470	1.36	2.25	11%	26%	9.00	4.00
Mali	$95,764	$27,361	$152,512	$100,661	$25,184	$87,470	1.36	2.25	11%	26%	9.00	4.00
Senegal	$95,764	$27,361	$152,512	$100,661	$25,184	$87,470	1.36	2.25	11%	26%	9.00	4.00

Table 21: portfolio analysis (1 solar mini-grid)

Program																	
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**Undiscounted net benefit with externalities**	**Undiscounted net benefit without externalities**	**S-NPV**	**NPV**	**S-IRR (lifetime)**	**IRR (lifetime)**	**S-Benefit to cost ratio (lifetime) / discounted**	**Benefit to cost ratio (lifetime) / discounted**	**S-Payback Period (Years)**	**Payback Period (Years)**	**Debt Service Coverage Ratio - Farmers organizations**	**Debt Service Coverage Ratio - MSMEs**	**Debt Service Coverage Ratio - COOPERATIVES**
Burkina Faso	$17,064,688	$10,944,444	$20,859,393	$14,632,665	$44,003,859	$16,311,329	$19,620,133	$4,769,985	24%	10%	2.15	0.99	5	8.00	1.67	1.67	1.67
Ghana	$12,798,516	$8,208,333	$15,644,544	$10,974,499	$33,002,894	$12,233,497	$7,121,240	$352,069	24%	10%	1.72	0.67	5	8.00	1.30	1.30	1.30
Ivory Coast	$12,798,516	$8,208,333	$15,644,544	$10,974,499	$33,002,894	$12,233,497	$17,367,388	$4,732,043	24%	10%	2.26	1.09	5	8.00	1.36	1.36	1.36
Mali	$17,064,688	$10,944,444	$20,859,393	$14,632,665	$44,003,859	$16,311,329	$23,156,517	$6,309,391	24%	10%	2.26	1.09	5	8.00	1.88	1.88	1.88
Senegal	$17,064,688	$10,944,444	$20,859,393	$14,632,665	$44,003,859	$16,311,329	$23,156,517	$6,309,391	24%	10%	2.26	1.09	5	8.00	1.68	1.68	1.68

Table 22: portfolio analysis (Program)

6.1.2. Solar mini-grids – Banks discount rates

Table 27 and Table 28 show the performance of solar mini-grids when using the rates requested by commercial banks. The 1item investment shows positive NPV, BCR, and IRR only in, Mali, indicating that this investment may be profitable only in that country. Also the program analysis indicates that Mali is the only country with a positive NPV, even though the BCR is negative. On the other hand, the debt service coverage ratios are always > 1 for all the beneficiaries in all countries except Ghana. This indicates that that the beneficiaries would be able to repay their debt in at least four of the five countries considered in this study.

One mini-grid												
Mini-grids	**Total investment**	**Project contribution**	**Revenues generated**	**Value of externalities**	**NPV**	**S_NPV**	**BCR**	**S-BCR**	**IRR**	**S-IRR**	**Payback Period (Years)**	**S-Payback Period (Years)**
Burkina Faso	$95,764	$27,361	$152,512	$100,661	$(987)	$29,808	0.98	1.61	11%	26%	9.00	4.00
Ghana	$95,764	$27,361	$152,512	$100,661	$(11,113)	$7,674	0.73	1.19	11%	26%	9.00	4.00
Ivory Coast	$95,764	$27,361	$152,512	$100,661	$(1,875)	$27,860	0.96	1.58	11%	26%	9.00	4.00
Mali	$95,764	$27,361	$152,512	$100,661	$6,687	$46,665	1.12	1.85	11%	26%	9.00	4.00
Senegal	$95,764	$27,361	$152,512	$100,661	$(1,875)	$27,860	0.96	1.58	11%	26%	9.00	4.00

Table 23: portfolio analysis (1 solar mini-grid)

Program																			
Mini-grids	Total investment	Project contribution	Revenues generated	Value of externalities	Undiscounted net benefit with externalities	Undiscounted net benefit without externalities	S-NPV	NPV	S-IRR (lifetime)	IRR (lifetime)	S-Benefit to cost ratio (lifetime) / discounted	Benefit to cost ratio (lifetime) / discounted	S-Payback Period (Years)	Payback Period (Years)	Debt Service Coverage Ratio - Farmers organizations	Debt Service Coverage Ratio - MSMEs	Debt Service Coverage Ratio - COOPERATIVES		
Burkina Faso	$17,064,688	$10,944,444	$20,859,393	$14,632,665	$44,003,859	$16,311,329	$6,327,513	$(815,412)	24%	10%	1.52	0.56	5	8.00	1.27	1.27	1.27		
Ghana	$12,798,516	$8,208,333	$15,644,544	$10,974,499	$33,002,894	$12,233,497	$770,065	$(2,086,991)	24%	10%	1.08	0.33	5	8.00	0.99	0.99	0.99		
Ivory Coast	$12,798,516	$8,208,333	$15,644,544	$10,974,499	$33,002,894	$12,233,497	$4,366,902	$(761,508)	24%	10%	1.49	0.54	5	8.00	1.09	1.09	1.09		
Mali	$17,064,688	$10,944,444	$20,859,393	$14,632,665	$44,003,859	$16,311,329	$10,914,717	$1,058,290	24%	10%	1.80	0.72	5	8.00	1.46	1.46	1.46		
Senegal	$17,064,688	$10,944,444	$20,859,393	$14,632,665	$44,003,859	$16,311,329	$5,822,536	$(1,015,344)	24%	10%	1.49	0.54	5	8.00	1.21	1.21	1.21		

Table 24: portfolio analysis (Program)

Annex 1: documentation of models and assumptions

Solar mini-grids

INVESTMENTS	
Capital costs	See Annex 23
O&M costs	See Annex 23
Indirect Benefits	
Avoided Carbon	See Annex 23
Average annual additional income generated	GOGLA, a global association for the off-grid solar energy industry indicated that Solar House Systems in West-Africa can generate an average additional monthly income of 27 USD in rural areas (GOGLA, 2019).
Direct benefits	
Electricity cost BAU	The World Bank (2017) and IED (2013) suggest that electricity prices in Sub-Saharan countries range from 0.6 to 1.0 USD/kWh. In this study, we used 0.8 USD/kWh as average price.
Annual Revenues	See Annex 23 ($ 0.27 per kWh or own estimate)

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